VOLUME VII. NUMBER 6

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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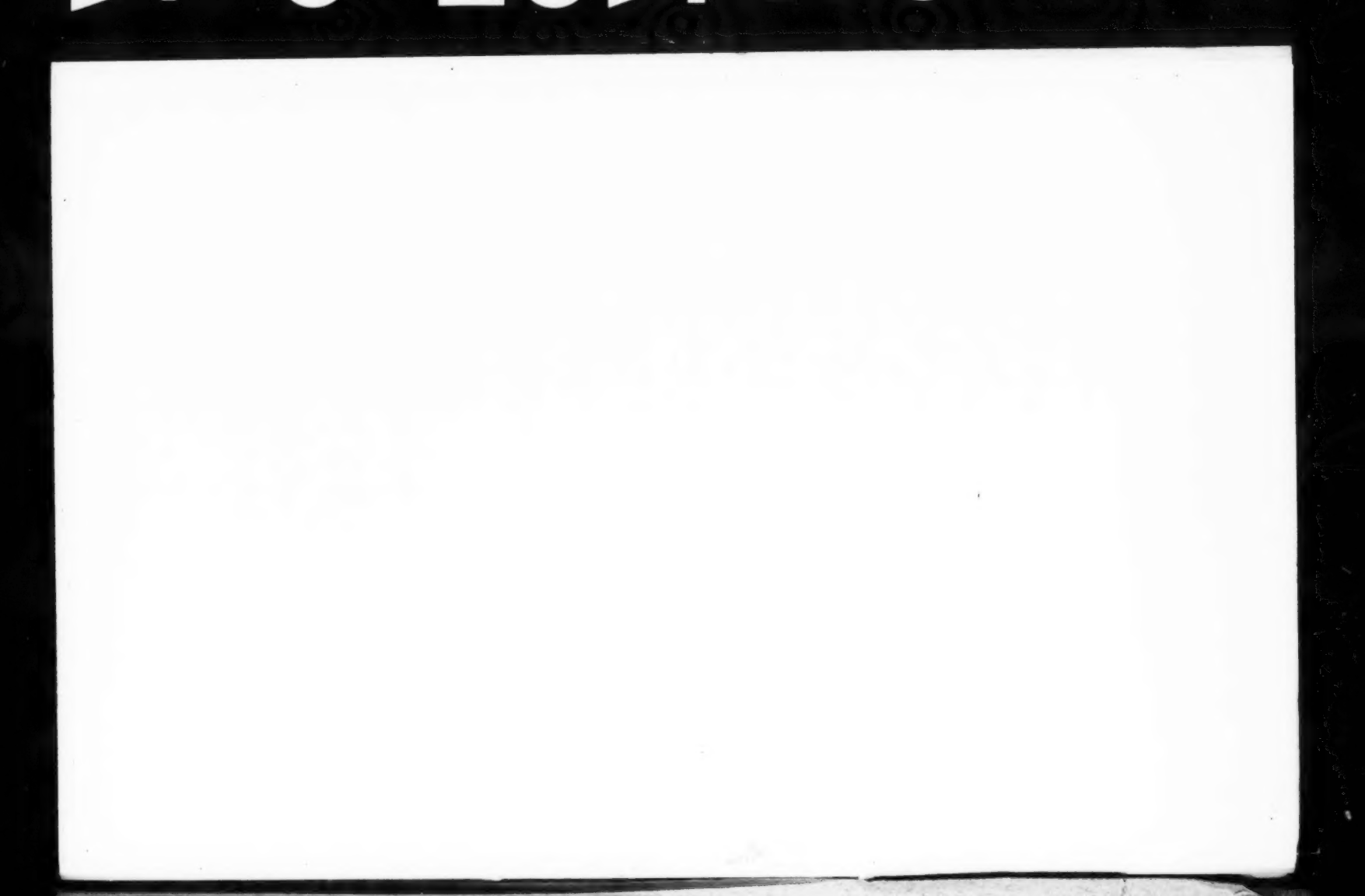

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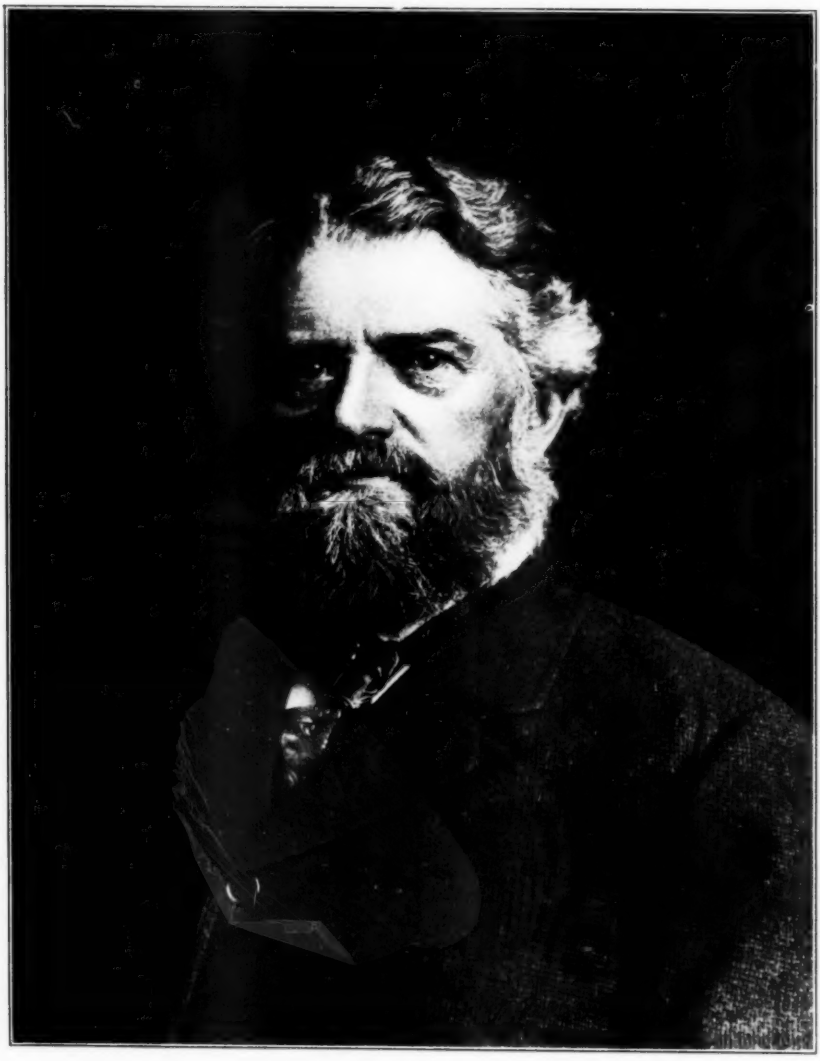

Simon Newcomb

Born March 12, 1835; died July 11, 1909

Journal of the Royal Astronomical Society of Canada, 1913

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SIMON NEWCOMB — HIS LIFE AND WORK*

BY JOHN A. PATERSON

PROFESSOR SEE, of U. S. Naval Observatory, a collaborator of the subject of this sketch, has written the words:

"By the death of Professor Simon Newcomb at his home in Washington, July 11th, 1909, America has lost her foremost man of science of this generation, and the world is deprived of one of the greatest astronomers and mathematicians of all time. He was notably great as an investigator in all that relates to the physical sciences but also as a thinker and all-round natural philosopher. In this larger aspect he was, undoubtedly, the foremost man of science of our time."

These are strong words, and after making all due allowance for the personal touch of friendship, and for a national pride, both of which are not only pardonable but laudable, we must conclude that there must necessarily be more than one strong determining factor upon which such a judgment has been founded. We are standing too close to the canvas of history

* Report of an address delivered before the Royal Astronomical Society of Canada, April 1, 1913.

upon which has been projected this man's work and life to justly estimate them and place them in their proper relation, and judge of their due proportion. We look back through the mist of years and we see the immortals looming up large and conspicuous — Copernicus and Tycho, Kepler and Galileo, Newton and Laplace, Herschel and Bessel, Argelander and Vogel. But the race that provided such men is not effete ; scientific lineage still lives ; intellectual ancestors still produce intellectual descendants and Astronomical Science is still enthroned. In the calm, cold atmosphere of a later day, when personal friends have passed away, the works of great men will be better understood, their scientific influence will then be more deeply, and, therefore, more truly felt, and they will fall into their true places on the ever increasing roll of intellectual achievement.

We all like to know great men. We all like to touch great men even physically and still more so intellectually. There is something broadly human in the relic hunter and the souvenir collector. The worshipper cannot be satisfied with a vague idea, hence the idolater clutches something physical, and it is the same principle actuates the worshipper at the shrine of a great man. Do you recall how Browning looked upon a man who had spoken to Shelley ?

> "Ah! did you once see Shelley plain,
> And did he stop and speak to you,
> And did you speak to him again ?
> How strange it seems and new !"

Let us try to night and see Newcomb "plain" and let him stop and speak to us, and we may in thought speak to him in turn, and thus we will know him better, and, perhaps, touch the secret springs of his great and brilliant success. And after all we will find that there is nothing new in these springs, for they are as old as Hipparchus, whom Ptolemy describes as a "labor loving and truth loving man" ; aye, and even older, for genius is after all the faculty of taking infinite pains. Newcomb was a Canadian by birth. The world found him in 1835 at a little town in Nova Scotia. His first venture into the business world

was in 1851 when he became apprenticed to a certain Dr. Foshay, who undertook to teach young Newcomb the art and practice of medicine. One interesting relation in recorded, that the druggist in St. John who supplied this doctor with medicines was S. L. Tilley, afterwards Sir Leonard Tilley, the Finance Minister of Canada, and thus young Tilley and the still younger Newcomb often met, but then the mysteries of finance were as far from the one as the mysteries of the stars were from the other. Newcomb soon tired of the medical drudgery of making pills and searching the fields for herbs and he sighed for fresh fields and pastures new —the eaglet could not be caged with the sparrow; he was not fitted for weighing powders, but for weighing planets, not for mixing medicine but for unravelling the problems of the universe, but he did not then know that. He knew not whither he drifted but as surely as the stellar systems are guided by the divine hand so too was Newcomb guided to his manifest destiny. The result was that he most prosaically took flight, and without any money or even change of clothes worked his passage on a boat and reached the United States and obtained employment in Maryland at Massey's Cross Roads as a teacher. This gave him an opportunity for the study of mathematics. While on a visit to the Smithsonian Institution, at Washington, he saw in its library a book which fired his ambition and changed the future course of his life — and that book was Bowditch's translation of Laplace's "Mécanique Céleste." Soon thereafter, in 1857, he emerged from his chrysalis condition and entered what he called "the world of sweetness and light" as a computer on the *American Ephemeris and Nautical Almanac*, at Cambridge, Mass., at a salary of $30 per month.

It is good in these days of wasting luxury to emphasise the noble product of a simple poor home where there were more dolors than dollars and more sacrifices than shillings and where education had to be fought for, and saved for, and stinted for and well nigh starved for. There are cases where money has been able to command a certain amount of favor among students of science, but as a general rule wealth and luxury are not

associated with steady industry because luxury enervates and undermines effort, and without effort there can be no science. All the greatest men of science in the past have been comparatively poor. The principle is clear for those who can buy things with money obviously will not work for them, and, since there is no excellence without labor, "it is indeed easier for a camel to go through the eye of a needle than for a rich man to enter the kingdom of science." Poverty is the kindly whip to the mind to make effort; and so blessed be drudgery! The world owes much to poverty.

> "Seven cities claim the mighty Homer dead
> Through which the living Homer begged his bread."

Lagrange's father was once rich but subsequently lost his property, and the great mathematician was accustomed to say after he had become celebrated that if he had been wealthy he would have done little or nothing in mathematics.

But to return to the highway of our narrative, the *Ephemeris* or *Nautical Almanac* upon which young Newcomb trained his mathematical muscle is the wondrous book from which the world discovers all its knowledge of times and seasons, the places past, present and future of the planets, satellites and stars, the motions of the moon and of the earth, deals with eclipses and all predictable celestial phenomena. It is the bible of the navigator for with this book and an ordinary instrument the wayfaring man by land or sea can tell exactly where he is as he wanders, or is driven, over the face of the earth. Truly it is a lamp unto his feet and a light unto his path. Here is the magic wand that points the way abroad and leads the way homeward. The way of a bird in the air was to Solomon a mystery, but the way of a traveller on earth, or sea, or air, with this engine of paper, ink and leather is no mystery, for its contents are founded on the rock of impregnable mathematics and are as a dazzling beacon on the darkest night. To young Newcomb this work was no drudgery, to his mind it became transformed as if it were some divine thing. If the world had no enthusiasts, what would it be

but a dull, dreary desert? This is how he elevates the *Nautical Almanac* to the very skies; these are his words: — "To this work I was especially attracted because its preparation seemed to me to embody the highest intellectual power to which men had ever attained. The matter used to present itself to my mind somewhat in this way: Supply any man with the fundamental data of astronomy, the times at which stars and planets cross the meridian of a place and other matters of this kind. He is informed that each of these bodies whose observations he is to use is attracted by all the others with a force which varies as the inverse square of their distance apart. From these data he is to weigh the bodies, predict their motion in all future time, compute their orbits, determine what changes in form and position these orbits will undergo through thousands of ages and make maps showing exactly over what cities and towns on the surface of the earth an eclipse of the sun will pass fifty years hence or over what region it did pass thousands of years ago. A more hopeless problem than this could not be presented to the ordinary human intellect; there are tens of thousands of men who could be successful in all the ordinary walks of life, hundreds who could wield empires, thousands who could gain wealth, for one who could take up this astronomical problem with any hope of success. The men who have done it are, therefore, in intellect the select few of the human race — an aristocracy ranking above all others in the scale of being. The astronomical *Ephemeris* is the last practical outcome of their productive genius."

These are, indeed, brave words, and give one a great uplift, but it must be remarked that the work of the astronomer is not carried on in beautiful gentleness, for its results are reached, as results in all lines of physical and mental activity are reached, through sacrifice and suffering, and no man knew this better than Newcomb. Most people have a very vague idea of what astronomers apply themselves to, they are popularly believed to be observing through telescopes, looking at stars, trying to discover something and sending an account to the newspapers if they discover anything. But to reach even the poorest result they

have to pull hard at the skirts of Urania, who is niggardly in her gifts, they "scorn delights and live laborious days" aye and nights too, not, indeed, *noctes ambrosianæ* not, indeed, nights pregnant with the balm of summer zephyrs, but nights in which one "feels the season's difference and oft the churlish chiding of the winter's wind even till they shrink with cold." "The popular fancy depicts the astronomer in a luxuriously easy attitude at the working end of some huge leviathan of a telescope studying the ever shifting panorama of the heavens, the beauties of Mercury the swift messenger of the gods, the splendors of silvery Venus, the dashing glories of battle-colored Mars with its snows and clouds and moons and water channels delightfully suggestive of engineering, the tempestuous clouds of Jupiter with his mysterious belts and his moons chasing each other round and round hiding behind his back, trembling like glittering beads on his edge and dashing across his disc. For the astronomer, exists Saturn with his girdling belts and many moons and when he tires and grows blasé of these common things, he is supposed then to turn his telescope to the flaming bannered field where the bright stars encamp, and where their glittering hosts forever parade under star chiefs who utter no word of command, but move, and wheel, and govern all their brilliant equipment." For the astronomer the heavens reveal the luminous hazes called nebulæ, the chaotic amorphous masses of world-stuff which may be the cradles of new universes, or, perhaps, wrinkled decadent systems, or, maybap, the catafalques or even the sepulchres of extinct cosmogonies. For all these, astronomers are assumed by the great extra-public to live and look, and if they do not discover something, then, indeed, they are popularly supposed to be mere worthless bipeds, mere cumberers of the ground, unsuccessful fishermen who have fished and caught nothing, and deserving of the scorn and contumely of their fellows, deprived too of the chance of piscatorial utterances void of truth, for in such a case the astronomer must show his catch, be it ever so small, a planetoid, a comet or a *nova* — even if it is a fleeting meteor he has seen hurtling across the sky he dare not

lie, because if it was real others must have seen it, and they are all there to bear witness unsympathetically.

But under sunshine or shadow Newcomb held on his way and followed the gleam right up to the sacred palaces of Truth. In 1861 Newcomb applied for the professorship of Mathematics in the United States Navy and soon after received his commission duly signed by Abraham Lincoln. He then worked at the Naval Observatory in Washington with the meridian circle and the nine-inch equatorial — but his heart was more wrapped up in the study of pure mathematical astronomy rather than in taking observations. The great Sir Isaac was not much of an observer, but he was mighty in the pure mathematics as applied to astronomy ; Kepler was the observer who declared his great laws from a multitude of observations, while Newton proved the truth of the laws and showed how the universe was fashioned and governed, without any observations and from pure reasoning, taking his calculus and the law of gravity as his only instruments. He could have written his *Principia* and unravelled the problem of the universe if he had been as blind as Milton.

There was at this time, 1870, no large telescope in America, and Congress was asked to supply the necessary money, which it did after much vexatious delay and objection, because these august men could not see what practical use a large telescope could be. The price was limited to $50,000 and the firm of Alvan Clark & Son were the makers. In 1875 this fine 26-inch refractor was turned to the firmament. It was used in the measurement of the satellite system of Uranus and Neptune and material was thus obtained for an improved determination of the masses of these two planets. In 1877 with this instrument the satellites of Mars were discovered, and thus the casket within which the secrets of the sky were locked was broken open. This Washington refractor was then the largest in the world ; after that the Clarks undertook and carried out successfully larger undertakings. A 30-inch for the Pulkova Observatory in Russia, a 36-inch telescope for the Lick Observatory in California, and

finally the 40-inch for the Yerkes Observatory in Chicago were the results.

Newcomb also took a leading part in organising expeditions for the transit of Venus in 1874 and 1882. He was the Secretary of the Transit Commission for 1874. It cost Congress $175,000 and the transit was not visible in the United States; eight parties were sent to the other side of the globe, three to China, Japan and Siberia, and five to islands in the Pacific and Indian Oceans. On the whole the weather was bad and the number and value of the observations were more or less impaired. The transits of Venus occur very rarely, they come in pairs, with an interval of eight years between the transits of a pair; a pair occurred in 1761 and 1769, and again in 1874 and 1882. There will be none in this century and our posterity will see another pair in 2004 and 2012. The phenomenon is valuable as upon it depends a certain calculation for the parallax of the sun, from which the distance of the sun from the earth is calculated; this distance is a very important unit of measurement, for it is used as a sort of foot-rule to measure up other distances in the solar system. In astronomy we do not think in miles or even thousands of miles; millions are the unit, and so this distance of the sun from the earth, being 92,790,000 miles or so, is important as it is the basis of other calculations and governs other distances. In 1874 it was thought that the transit of Venus presented the best phenomenon from which to deduce the sun's distance, but since then the application of the known velocity of light has been used, and the distance has been more accurately measured by estimating how long the waves of light take to reach our eyes from the sun. In 1882 Newcomb headed an expedition to the Cape of Good Hope to observe the transit. The sky was wonderfully clear and the expedition was most successful. These expeditions in 1874 and 1882 cost the United States Government $375,000 and Newcomb records the extraordinary fact that all the Governments who sent out transit expeditions, except that of the United States, completed long ago the work of reduction and published their observations and

the results in full. But for various reasons which it is difficult for men who are neither astronomers nor politicians to understand down to 1904, being thirty years after the first transit, nothing official has ever been published and Newcomb adds "whether it will ever appear is a question for the future. All they who took part in it or who understood its details are either dead or on the retired list and it is difficult for one not familiar with it from the beginning to carry it to completion." This is rather a sad commentary on the operations of a great democracy for this result, or want of result, was not the fault of the astronomers. "Vox populi" is not always "Vox dei," in fact it very seldom is. Even the Czar of Russia, much maligned as he is, managed the publication of the Russian transit expedition better —a one-man government is often better than a 100-million man government.

In 1877 Newcomb became Superintendent of the *Nautical Almanac*, and this position he held for twenty years, until his retirement in 1897, and during that time he revised and improved the tables of all the planets of the solar system, prepared catalogues of the fixed stars and carried on important researches on the motions of the moon.

Newcomb when at Cambridge took up the special study of the asteroids, those mimic planets that revolve between Mars and Jupiter. The astronomer Olbers had given currency to the theory that these baby worlds were the fragments of a once large planet which had become disrupted through an explosion or collision, but this theory has been exploded into more fragments than the asteroids themselves. If there ever existed such a parent body then the orbits of these fragments (if such there ever were) would at some remote time have passed through some common point, which would have been the position of the parent body at the time of this disruption. Newcomb investigated that problem and, in a paper upon "The Secular Variations and Mutual Relations of the Orbits of the Asteroids" read in 1860 before the Academy of Arts and Science, proved by abstruse mathematical reasoning that no such common point ever existed.

To trace back for several hundred thousand years the orbits of these asteroids through all their numerous variations, relations and perturbations between themselves and from other planets and to prove that they never had any point of intersection is surely one of the greatest triumphs of the human intellect, surpassing one would almost say the discovery of Neptune. Verily the topmost branch of the tree of knowledge has been bent down by human effort whence the golden fruit of success has been plucked.

Newcomb made for many years important researches on the motions of the moon. The problem of the three bodies has been the crux of the astronomers. If there were two bodies only, say the sun and the earth, then at any instant of time the exact place of each could be determined, their exact orbit and their exact velocity, for they would move round their common centre of gravity in an ellipse and this ellipse would never change its form or size or position, for the force of gravity alone would dominate the system and its law is simple and clearly understood; but the moment you introduce a third body, then presto! change, the whole problem becomes complicated and the orbits change in form, size and position and the bodies relatively change their velocity and even their form. But add to the third body a fourth and a fifth and a sixth and then the whole retinue of the solar system with their satellites and a system of comets and all the fixed stars all operating on each other by the force of gravity and then let the mathematical astronomer sit down and apply his calculus and he will find it indeed hard, aye impossible, to put the winter of failure behind him and the summer of success in front of him. Consider it. The action of Jupiter on the earth this moment has an effect that changes her motion for ever and so too the action of the earth on Jupiter. Carlyle though not a professional mathematician puts its strongly — "Knowest thou, if thou but cast a stone on this earth, thereby thou changest the centre of gravity of the universe?"

Newcomb took up the tables of the moon by Hansen, a distinguished German astronomer, and investigated the question

whether she was exactly following the course laid out for her by Hansen's tables. Juliet would not let her Romeo swear by "the *inconstant* moon" and so Newcomb found it, because by his observations for a year or two it was found that the moon was falling behind her predicted motion, and soon this ceased and then she went ahead of her predicted motion. Laplace had been perplexed by what are called "the inequalities of long period." For a number of years, perhaps fifty, the moon would seem to be running ahead and then she would relax her speed and fall behind. Laplace could not explain this. Hansen suggested the action of Venus which caused the moon for 130 years to run ahead and then for 130 years to fall behind, like a pendulum. But the moon would not keep time with Hansen's tables. Newcomb made elaborate investigations and observations and delved into old records of observations before 1750 in Pulkowa and Paris during the time of the Franco-Prussian war, even with the siege guns sounding in his ears and it was discovered that Hansen's tables were in error. This work of Newcomb's went on until his death in 1909. About 1902 the Carnegie Institution made a grant to enable him to employ necessary assistants. In 1908 Newcomb became very ill with internal cancer and in consequence his work on the motion of the moon was rushed to completion with all admissible speed and finally he dictated the last of the memoir on that subject about three weeks before he died. This work occupied him for forty years.

This paper would be incomplete without some reference to our conference with Newcomb here at the time of the meeting of the British Association at Toronto in August, 1897. This Society then came into direct conflict with his views as to the uniformity of time reckoning. There are no less than three systems of time reckoning; the nautical day commences at twelve o'clock noon the day before and ends at twelve o'clock on the day in question; the astronomical day commences at twelve o'clock noon on the day in question and ends at twelve o'clock on the next day; the civil day commences at midnight and ends twenty-four hours thereafter at midnight. It was proposed to get rid of this con-

fusion by fixing on a twenty-four hour period that would be the same for the astronomical, nautical and civil day. In 1884 an International Meridian Conference held at Washington favored this unification. The Astronomer Royal and Newcomb and a few others opposed the change upon the ground that this would introduce confusion and might endanger navigation, it being thought that the present confusion might better continue than be cured. The world has been so accustomed to disorder that order would be dangerous. Sir Sandford Fleming took a great interest in this matter and desired the British Association at their fourth meeting to express some view upon it; the late Mr. George E. Lumsden and Mr. Thos. Lindsay were also strong supporters and this writer was asked to write a paper on the subject, which he did, and he had the honor to read it before the British Association and to have it recorded in its proceedings. Like many other documents of a much abler and more valuable character it was securely buried, more securely than Hamlet's father who would insist most inconveniently in taking midnight walks and making midnight speeches. After it was read some committee was appointed to give it what was called a consideration, but Newcomb said about three words adversely and nothing more was done - that "cloud-capped tower and gorgeous palace" of a most reasonable reform fled like "the baseless fabric of a vision." Such a reform still waits for the reformer. I think it fair to record this, for it forms a node where the orbit of Newcomb crossed the orbit of the Royal Astronomical Society of Canada and nearly a collision, but only a partial eclipse happened.

Ordinary men like ourselves read with wonder a paper referred to in the monthly notices of the R. A. S. for January, 1909, in which Newcomb definitely gives up the hope that the theory of gravitation will explain all the movements of the moon. Then there must be some other undiscovered law which Nature holds in her clenched fist and has not yet revealed, that supplements or modifies Newton's sublime discovery. We have thought all along that the Law of Gravitation was so strongly embedded

in the constitution of matter and throughout the universe, and that it was the only Sovereign that held sway so absolutely that even the gates of hell could not prevail against it. Some inequalities in the moon's motion called "fluctuations" are held to be entirely different from the irregularities which are traceable to gravitational causes. If this be true one is apt to wonder what is truth? And where is she to be found? And is Newcomb after all another Newton? And is there some defect in the armor-plated *Principia*? See has proved, he says, that there is a cause accelerating the earth's rotation and thus counteracting the secular effect of tidal friction in retarding the earth's rotation. If a globe is set rotating and a cloth is held touching the globe the friction thus set up would assuredly gradually slow down the rotating globe. The tides acts as a brake like the piece of cloth. It is suggested that this cause that so accelerates the earth's rotation and so balances the effect of tidal friction is, in some way not yet explained, connected with this more than suspected new law that modifies gravitation.

Newcomb was a tireless worker. He investigated the orbit of Neptune and constructed general tables of his motion and afterwards he undertook a similar piece of work with the planet Uranus. The result of these investigations appeared in the "*Smithsonian Contributions to Knowledge.*" In the years 1880-1882 he made a determination of the velocity of light by the Foucault method and by a skilful construction of the necessary instrument he reached an extraordinary degree of precision which brought out the concluded value far in advance of all previous determinations. He contributed a vast number of notes on almost every conceivable topic in astronomy and the allied sciences to scientific periodicals, and I find it noted in "*The Annals of the New York Academy of Science*" that the Royal Astronomical Society of Canada published a bibliography.

He also had his side issues, he notably had a vocation, but he went on literary vacations, for he contributed to the world treatises on political economy and also psychics, and even wrote a novel.

It is popularly supposed that mathematicians are only devotees of the "cross-grained Muses of the Cube and Square" and no more, but some rare souls can make delightful excursions beyond the "Theory of Fluxions" into the beautiful garden of Imagination. As the curved line of a hyperbola always approaches but never reaches its asymptote, so the men of mathematical skill are often found making infinitely near approaches to the lines of Poetry and Romance. Charles Lutwidge Dodgson, the English Mathematician, astonished not only himself and the world but also delighted the world with his "*Alice's Adventures in Wonderland*" and "*Through the Looking-Glass and What Alice Found There*." He was in that literary pose known as Lewis Carroll. Indeed the comparison of the asymptote hardly holds with him for his romantic skill was not a tangent at infinity but a tangent a long way on the determinate side. It would almost seem that Mr. Dodgson felt that he was unbending himself from his mathematical solemnity for he makes Alice parodize thus,—

> "You are old Father William," the young man cried,
> "And your hair has become very white,
> And yet you incessantly stand on your head,
> Do you think at your age it is right?"

Did the author think he himself was "standing on his head" when he wrote this most beautiful romance of the nursery? Here follows the explanation, and witty apology,

> "In my youth" Father William replied to his son,
> "I feared it might injure my brain,
> But now that I am perfectly sure I have none,
> Why I do it again and again."

But let us again pick up the thread of our story from these ravellings or revellings. Newcomb was deservedly honored by his fellowmen; to be esteemed by his age is one of the most valued assets a man can have. A great man of affairs, one who had sounded all the depths and shoals of human nature, a king among men, and also a king of letters, centuries ago said "Seest thou a man diligent in business, he shall stand before kings, he shall not stand before mean men," and that was true of Newcomb,

for six American and eleven European universities enrolled him among their honorary doctors. He held membership in all the great European and American Scientific Societies and has been President of a great number. A degree in the University of Toronto and an honorary Fellowship in our own Royal Astronomical Society of Canada are among the number.

With Newcomb it grew late and dark on the 11th of July, 1909. He had a public funeral attended by the President of the United States, the high Officers of State and the aristocracy of men of science. And so the years roll onwards and scientific discovery closes one volume to open another and yet another. We see at the best in a glass darkly, and most things we cannot see, and little that we do see can we truly interpret. Eclipses may be calculated, orbits of double stars may be measured and intellectual conquests of a very high order may be achieved, but when we consider the vast problems of physics and astronomy the Masters of Science are at the best but

> "Children crying in the night,
> Children crying for the light,
> And with no language but a cry."

Our intellects are given to us to use them, to cope with lofty difficulties and to surmount them; let us as humble students use what mind and gift and opportunity we have.

> "God did annoint thee with His odorous oil
> To wrestle, not to reign."

It is the oil of the palæstra we have and not the chrism of a king. Let us wrestle here valiantly, earnestly, honestly and prayerfully, no matter whether successfully or not, and we shall reign there.

NOTES ON THE GREAT METEORIC STREAM OF 1913, FEBRUARY 9TH

SEEN IN CANADA AND THE UNITED STATES

By W. F. Denning

PROFESSOR CHANT, in the Journal of the Royal Astronomical Society of Canada, for May–June, 1913, has given us an extremely interesting and valuable paper on the extraordinary flight of meteors witnessed across Canada and the United States on February 9, 1913. That meteoric exhibition seems to have been unparalleled in two respects *viz.*:—(1) Its multiple nature, consisting as it did, of a long procession of meteors. (2) The great length of its observed luminous flight extending over more than one-tenth of the earth's circumference.

I have been in the habit of watching the heavens since 1865 and have never noticed anything similar. There are meteors occasionally seen with multiple, crumbling heads and broad spark trains, but the wonderful stream of successive meteors seen on February 9 seems, like Saturn's rings, without a parallel.

Professor Chant has made some useful deductions concerning the real course of the meteoric stream, and of its height as it passed between the eastern border of Lake Huron and Buffalo, but the data, upon which he necessarily had to rely, are rather contradictory, and absolutely accurate results cannot be obtained from them. I have partially gone over the work again, and the results obtained exhibit a good general agreement with those derived by Professor Chant. I am, however, disposed to give the objects a rather greater elevation than that assigned by him. Taking the whole of the estimates of the altitude, I should ascribe a height of about 38 miles as the meteors passed over the region near Toronto. There are a few significant observations indicating the lower elevation mentioned by Professor Chant,

but there are also a great number supporting the conclusion that the objects were decidedly more than 30 miles high. Several reasons support this, *viz.*:—(1) The great improbability that the stream could have prolonged its flight so far in a fairly dense region of air only 26 miles above the earth's surface. (2) The red or yellow, slow meteors, moving in horizontal flights, are usually more than 30 miles high, and generally between 36 and 40 miles. In cases of very slow fireballs, falling at a slight angle towards the earth, they frequently penetrate deeper, collapsing between 32 and 26 miles, and rarely go farther. I have computed the heights of a considerable number of meteors, moving in long horizontal paths and they have almost invariably been more than 40 miles above the earth's surface. The objects seen in February last may, however, have been abnormal in their elevation as well as in their distribution.

The data are of such a character that everyone studying them may derive a different result according to his interpretation of the records. The following remarks are, therefore, merely intended as independent views, and are in no sense offered in the light of criticism.

The mean height of the objects from many observations in the region between longitude 82° and 78° West was 38 miles. Some of the components seemed higher than others, and ranged, perhaps, up to 44 miles. But the observed differences in the apparent altitude of the meteors may have been possibly induced by considerable width in the stream rather than by actual differences in height of the particles.

The velocity was about 8 miles per second. The motion of the meteors was direct like that of the planets, and comets of short period.

If we adopt three minutes as the period occupied by the whole stream in passing a given spot, its length must have been 1440 miles. The earth was running away from the meteors at the rate of about 18 miles per second.

The observed path of the stream extended over 2,600 miles from N.W. of Mortlach, Saskatchewan, to E. of Bermuda.

The position of the "trace" or track over which the meteors passed is, no doubt, well placed by Professor Chant. The writer would be inclined to locate it two or three miles south of the line adopted, but there are uncertainties due to the conflicting evidence, and the positions shown in Professor Chant's maps, probably represent the best deduction that can be made.

The stream must have had a curved flight, fairly concentric with the earth's surface. Had it been travelling in a straight horizontal line without any curve or deflection, and 38 miles high near Toronto — it would have had a height of 250 miles at the beginning and end of its observed luminous flight owing to the earth's curvature. Of course it could not travel in any such straight line owing to air resistance and gravitation. There is no well attested case of a meteor ever having been seen at anything approaching the latter elevation and it is probably far outside even the rarer limits of our atmosphere.

The stream seems to have consisted of from ten to twenty groups, or meteors with fragments in the form of spark trails, including in all several hundreds of particles. The larger ones were probably traced over 180 miles by individual observers, and the duration was 23 seconds.

Had the stream met the earth in her orbit and moved east to west the velocity would have been about 44 miles per second, and the interval occupied in passing a given point 33 seconds. The motion at the end does not appear to have been very different to that remarked at the beginning. Judging from the aspect of the swarm as viewed from Bermuda it was not nearing exhaustion, but apparently quite capable of a further 1,000 miles or more flight across the North Atlantic Ocean.

It is probable that the stream may have developed from one mass originally, and that it was formed by one of the largest bodies of the kind we have ever encountered. The disintegration of meteors is a well attested fact of observation. The meteoric stones of L'Aigle, April 26, 1803, numbered two or three thousand, and their fall was distributed over an ellipse, of which the larger axis was 6·2 miles and the smaller 2·5 miles.

The meteorite of May 12, 1861, at Batnera, descended in fragments which were picked up several miles asunder, and they fitted precisely.

In any case the vanguard of the meteors of February 9 must have been of enormous size to have sailed with astonishing brilliancy, and retained their compact form, along a curved path of some 2,600 miles. Even after this extensive flight, Col. Winter, at Bermuda, where the last observation was made, says its diameter was equal to that of the moon. The testimony of various observers was that the chief bodies were subject to explosions scattering fiery sparks behind them in long trains. There was evidently a great expenditure of material going on along the whole line. The low velocity would certainly cause a vastly slower rate of combustion than that of meteors which dash into our atmosphere like the Leonids at 44 miles per second and acquire a white heat, destroying them instantly.

These meteors were red or yellowish-red and their color sufficiently showed the very moderate rate of combustion. It is generally the case that the apparently slow meteors overtaking the earth, and moving in nearly horizontal flights, last a long time, and travel over very lengthy paths. I found a path of 611 miles for the meteor of August 21, 1902, and a path of 590 miles for that of February 19, 1911, and they were probably much longer. The small area of England is not suitable for the determination of these long flights.

At Pense, the second station from whence the meteors of February 9 last were observed, the phenomena were described as a "procession of stars" lasting about two minutes.

At Bermuda, where the final view was obtained, Col. Winter estimated that the meteors occupied two minutes in passing a given spot, so that their enormously lengthy flight had certainly not extended the stream. This string of newly-made terrestrial satellites maintained the same relative distances from each other, without any lagging behind of the tail, even after encountering all the vicissitudes involved in a journey of one-tenth the distance around the earth. The times occupied in their passing

were not very exactly recorded, but no material lengthening out could have occurred. Probably the meteors existed in nearly the same distribution before their immersion, and combustion in our atmosphere. The resistance of the air, and terrestrial attraction, would seem to have counteracted the effects of the earth's curvature, and to have kept the stream well in tow, at a pretty equable height.

The tail end of the stream certainly did not consist of the same objects all along the flight, but was formed of burning fragments peeling off from the leading meteors. At Toronto, Mr. H. D. Ashley says that the last four meteors were extremely dim, and that two of them, observed to rise in the north-west, became invisible before passing over. Several of the larger meteors of the group doubtless existed all along the observed flight, while the smaller, scattered particles at the end were reinforced by luminous debris from the leaders in numbers sufficient to compensate for disappearances.

The reports from Fort William, Richard's Landing and Bermuda give evidence that the height was 60 to 80 miles when passing near these places. At Thamesville the swarm was seen below Cassiopeia and the polar star. The distance between these is about 28 degrees and taking 42½° as the altitude of Polaris, and that the meteors as shown in the sketch were as much as 12 degrees less, the resulting height must be 64 miles, the distance being 107 miles to the point on the earth underneath the meteors, and the altitude 30°. If we infer very considerable error in the proportions of the sketch and decrease the elevation to 25° we get a height of 51 miles, which seems probable.

As seen from Sudbury, about 190 miles north of the place under the southern point of the meteors' flight, they must have been quite 40 miles high, for there was a hill between the observers and the meteors which probably cut off fully 10° from the horizon.

At Winchester, some 5½° east and 1¼° south of Sudbury, the distance was 221 miles, and the altitude said to reach 15°. Taking the altitude as only 10° the height would be 45 miles.

There is decided evidence that the meteors were higher in the air, in the earlier and later part of their visible display, than in the middle section of their flight but not very considerably so.

In deriving the mean height near the middle part of the stream, (Toronto region), I deducted one-third of the estimated altitudes. In some cases this may not be sufficient, for there is a general propensity to overstate the elevation. But in other instances it is certainly taking off too much, for the given altitude is probably just about correct, and there are several descriptions where the estimate is obviously too high!

I believe that reducing altitudes by one-half the estimated values is too great. The difference between 45° and 23° is enormous, and few observers of ordinary intelligence, and exercising a little care, could make such an error. If a number of people are asked to give the altitude of an object 30° high, they will often say 45°—but 23° is so obviously nearer the horizon than the zenith, that very few estimate it as midway.

At Caledon East special weight has been given to the statement that "the meteors went over, or nearly over, the belt of Orion." They may, however, very likely have passed above it, and some of them certainly did, for they were at different altitudes.

There were two observers at Bolton, a little farther from the meteors than the Caledon one, and the independent estimates of altitude are:—"Some of them died out just as they passed over, though they were not directly over me, but a little to the south-west." "They appeared in the western sky about four-fifths of the way up from the horizon."

At Jackson, further west, but at nearly a similar distance from the meteors they were said to have passed nearly over head, but a little to the south-east. These statements indicate a path far above the belt of Orion even allowing for excessive estimates.

At Parry Sound Mr. W. L. Haight and a companion fixed the elevation as 35° to 38° after going back and determining its position from their point of view. Taking the altitude as really only 22° the resulting height will be 51 miles.

On page 157 of the article in the JOURNAL, Professor Chant gives nine values for the height, with a mean of 33·8 miles, after deducting half the estimated altitudes. I find that on computing from the same data, and correcting for earth's curvature, the mean comes out 35·8 miles, and I cannot explain the discrepancy. If one-third instead of one-half of the altitudes is deducted, the mean height is 51 miles, which certainly appears too great.

With regard to the thunder-like detonations, it is to be feared that endeavors to deduce the height from the time intervals elapsing between the appearance of the meteors and the reports, cannot lead to very certain or exact conclusions. The velocity of sound in ordinary air at 32° Fahr. is 1,088 feet per second or 12½ miles per minute, but we do not know accurately the velocity in the upper, colder and rarer regions of the atmosphere. We know that sound travels slower at low temperatures, and that loud explosions travel faster than faint ones. If computed on the basis of temperature at the earth's surface, the distance and heights of meteors determined from the noise of their bursting would be much too small.

At Mount Hamilton, California, a detonating fireball was very accurately observed in 1894, (July 27), and it was concluded that the sound was transmitted through an air medium with a mean temperature of — 193° Fahr. and sound velocity of 800 feet per second. The meteor exploded at height of 28 miles. The distance from Mount Hamilton was 59·25 miles and the noise occupied 390·7 seconds in reaching the observatory.

Mr. John Butterfield, at Toronto, heard the rumbling or thunder-like sound at $9^h\ 12^m$ on February 9, or seven minutes after the big leader of the meteor swarm had passed. If it was 38 miles high the observers distance from it was 47 miles. From the experiments made and knowledge gained, with regard to the decrease of temperature relatively to height it appears probable that the velocity of sound would not be more than 640 feet per second for a mean height of 19 miles which would give a distance of 51 miles — nearly agreeing with that observed by Mr. Butterfield. The data upon which these conclusions are based

cannot, however, be said to afford anything more than a rough approximation to the truth.

The radiant point of the meteors is uncertain. We know the direction of flight in azimuth, when the meteors were first seen from Mortlach and Pense, but do not know the inclination at which they were descending. If they were moving horizontally even at that probably very early period of their display, the point about 328°, + 9° — a few degrees east of ϵ Pegasi, was on the horizon in the direction 15° north of west indicated by the "trace" given by Professor Chant. If the meteors were in view before coming within range of the observer at Mortlach, it is certainly strange that there are no records from westerly towns in Alberta and British Columbia.

I draw the inference that the meteors first became visibly luminous in the region of Mortlach, Saskatchewan. As seen there, if they were falling a little towards the earth, the radiant must have been in the western region of the Square of Pegasus. I saw a meteor with extremely slow motion and a yellow train directed from this point on February 8 last, about 30 hours before the great display, and the fact has some interest as suggesting that there was certainly a meteoric shower in Pegasus at the time. But I can find no mention in former records of such a shower or of any fireballs from this quarter in the second week in February. The region sets soon after the sun.

Meteoric astronomy has, however, been sadly neglected in the past, and there are comparatively few accurate data available for reference. Of the myriads of fireballs which are annually displayed in the earth's atmosphere, not more than about a score are well observed and properly investigated.

There are probably more than a million meteors brighter than Venus appearing every year in the night skies of various parts of the world. If but twenty of these are subject to proper study we may form some conception as to the very few drops we gather of the great and continuous storm of meteoric fireballs.

February is becoming a notable month for abnormal meteors. Though August brings us its abundant Perseids, and November

its occasional brilliant showers of Leonids, February seems in recent years to have provided marvellous fireballs of a unique pattern, and quite unmatched in the history of meteoric astronomy. On February 8, 1894, there was a great daylight fireball, appearing in the sunshine soon after noon. On February 22, 1909, a fireball left a streak several hundreds of miles long which remained visible two hours, and drifted about 236 miles to the north-west over the English Channel and south-west of England.

Could photography have been applied and furnished a number of views of its path-position, the wonderful planetary swarm of February 9th last might have taught us some new and important facts. Its visit has certainly provided us with a great novelty among the transient phenomena of our skies. We must evidently be prepared to view the incursion of a strange object into the firmament at any time. The various forms of meteoric apparition are so extremely diversified that past researches have not nearly exhausted them. Observers are practically nonplussed by the surprise visits of remarkable meteors, and they ought to be better prepared and more alert, if they would improve upon the very defective observations made of past phenomena. The unique object of last February will direct a useful attention to the subject, and if it leads up to the making of but one new observer it will not have come in vain.

BRISTOL, ENGLAND,
September, 1913.

REMARKS ON MR. DENNING'S PAPER

The chief discrepancy between Mr. Denning's conclusions and my own is in the height of the meteors when passing Toronto.

In obtaining my result I used only observations on which I thought I had especial reason to depend. Mr. Hahn, who supplied the drawing for the frontispiece, besides being an artist is an amateur astronomer. He is the son of the late Otto Hahn, of Toronto, who possessed a large and valuable collection of

meteorites. Mr. Hahn's observation was closely corroborated by Messrs. Herman and Marsh, while four others, whose estimates appeared to be especially trustworthy, indicated a height not much greater.

In some of the other cases I had correspondence regarding the altitude, and I found the observer so often in doubt as to the value to be assigned that I decided to depend almost entirely on those few observations which appeared definite and certain.

As to the values in the table on page 157, I may say that in calculating them no account was taken of the earth's curvature. I thought them hardly deserving such refinement, but as the correction for curvature is always additive it would have been wiser to have allowed for it.

Mr. Denning, however, has had such a long and active experience in handling meteoric observations that his interpretation of the evidence is particularly valuable.

C. A. CHANT.

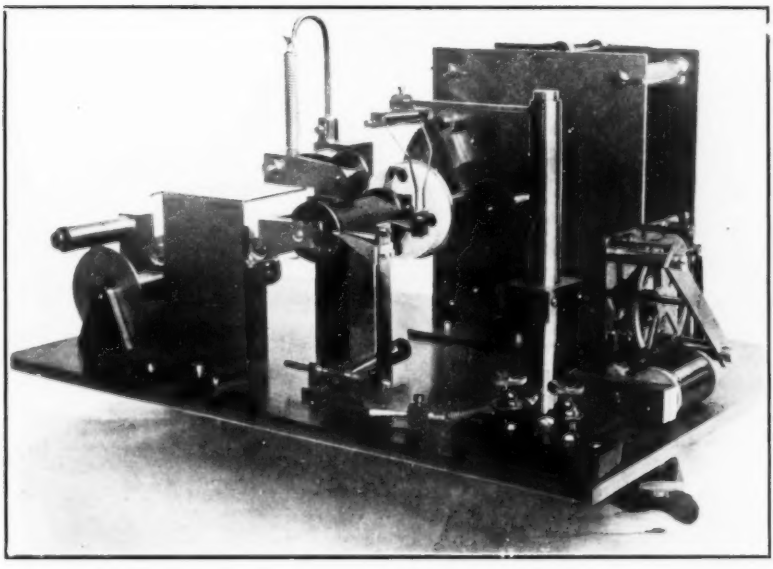
THE UNDAGRAPH

By Otto Klotz

Seismology as a science is of very recent date. Earthquakes have been noted from time immemorial, but we may say that it is only since the beginning of the present century that instrumental records are obtained that lend themselves to interpretations and analysis of the disturbance as manifested by the different kinds of waves propagated from the epicentre or hearth of the quake. Modern seismographs are highly sensitive, giving a magnification of at least a hundred, and are always damped, in order to eliminate as much as possible the swinging of the pendulum after being started by the first earthquake shock, for the seismogram is supposed to represent the earth movement, and not that of the bob of the horizontal pendulum, which should remain quiescent. A great improvement of late too has been made in the time-record, although at some stations the accuracy of one second does not yet obtain. The recently inaugurated world-time service, giving Greenwich time, from ten wireless stations at different hours throughout the 24^h, will make available for every seismograph station, not otherwise supplied with accurate time, a daily means of comparing its clock with standard time. It may be stated that a receiver for the wireless signals is on the market, and costs about fifty dollars (200mk.). In the series of the above wireless stations the two in North America are, Arlington (Washington) and San Francisco.

To get back to the seismogram. On it are recorded all movements of the earth, if of sufficient magnitude, but let it be added, that such magnitude is of microscopic dimensions generally. Of such movements and motion of an earth particle, the first place is occupied by that produced by earthquakes. These have a certain character or handwriting that the seismologist recog-

THE UNDAGRAPH



THE UNDAGRAPH, WITHOUT THE DIAPHRAGM STAND

Journal of the Royal Astronomical Society of Canada, 1913

PLATE XVII.

CHEBUCTO HEAD

nizes, and in a well-recorded quake he differentiates the different kinds of waves and their times of arrival, whereby the distance from his station to the epicentre becomes known within the limits of about 50 km., or 30 to 35 miles. The intensity and acceleration of gravity may be deduced too from the seismogram as well as the direction as shown by Prince Galitzin. However there are other disturbances also recorded by the seismograph. If a wind storm sweeps over the country the surface of the earth is set in motion, as well as buildings made to sway to and fro. This effect is seen on the seismogram by irregular lines, and by a deflection of the zero ; the latter, for instance, by a rapid increase of atmospheric pressure, thereby bending the surface of the earth and tilting the pier on which the instrument is mounted. But none of these latter records are mistaken by the seismologist as due to earthquakes. There is yet another disturbance, noted practically the world over on seismograms. It has the appearance of a more or less continuous serrated line, like saw teeth, with a period ranging from 3 to 7 seconds. The disturbance is more or less absent during the summer months, and is most prevalent during the winter months, or from October to April. It lasts hours, and sometimes days. The cause of these disturbances was puzzling. The writer began some years ago to make a daily comparison of our Weather Maps, which show the isobars across the continent, including Newfoundland and northward from the Gulf of Mexico, with the seismograms, following day by day the movement of the area of "Low" from the westward (northwest and southwest) down the great funnel of the valley of the St. Lawrence, the general course, out into the Atlantic. The result of this investigation was that whenever a Low appeared on our Atlantic coast, say from Cape Hatteras to Cape Race, Newfoundland, with steep gradients, microseisms — as we call these disturbances on the seismogram — were sure to make their appearance. As a matter of fact, with Weather Map in hand, one could predict with a very high degree of probability what would be found on the seismogram, as far as microseisms were concerned.

The disturbing element was thus found to be the water. It may be mentioned that a similar Low with just as steep gradients, but on land, had little effect and of a different nature, already referred to under windstorms. Professor Wiechert of Göttingen, from the records of their station, close to the sea, at Apia, Samoa, concluded that the microseisms were due to the beating of the waves on the shore or coast, a conclusion quite in keeping with the above, based on the position of Lows with steep gradients; for, without the latter there can be no storms or waves pounding the shores. To follow up the question still farther the International Seismological Association during its session at Zermatt in 1909, authorized its committee, of which the writer is a member, to have an instrument constructed which would record the ocean waves, at least their number in a given time, in order to determine the period of the waves, and to see whether such period is similar and of the order of magnitude of the microseisms as we find them on the seismogram. An instrument was built by the Cambridge Instrument Company after some time and installed at Tynemouth, and its record was shown by Dr. A. Schuster at the Manchester meeting in 1911. The period as shown by this wave-counter ranging from about 4 to 7 seconds was quite in keeping with the period of microseisms. The situation of the instrument, at the end of the pier at Tynemouth on the west side of the North Sea, is not one well adapted for the purpose of correlation between the period of the ocean waves and their corresponding period presumably shown by microseisms in Europe. The west coast of Ireland or of Norway would have been preferable. However practical difficulties stood in the way for mounting it otherwise.

A year or so ago correspondence was opened with the Cambridge Instrument Company with the view of obtaining an instrument that would not only record the number of waves but also their magnitude, for a complete correlation with microseisms requires such. However difficulties were anticipated in the construction giving those two elements, as well as in its subsequent supervision unless in skilled hands at the sea-shore station-

so that a wave-counter was eventually ordered by the Dominion Astronomical Observatory.

The instrument furnished, which I have named an undagraph, is a modification and improvement on the original one. Its principle is simple, being based on Boyle's law, PV = constant. An iron pipe is led into the sea, beneath the trough of the highest wave at low-tide. The sea-end of the pipe is open, while the other end leads into a small cell over which is a leather diaphragm, making when raised, electric contact, and other obvious mechanism records the same, and to which reference will be presently made.

The undagraph has recently been installed at Chebucto, outside of the harbor of Halifax, in latitude 44°30′N, longitude 63°31′W, where it is exposed to the broad waters of the Atlantic. It is in charge of the light-house keeper. The instrument is 120 ft. above sea-level on the granite cliff on which stands the light-house. The coast hereabouts is bold and rocky. A galvanized iron pipe 625 ft. long extends from the instrument over and down the rocks into the sea. The sea-end is 4-inch pipe, while the greater part is ½-inch, with short sections of 2 and 1-inch pipes between. Each wave passing over the open end causes the water to rise in the pipe, compress the air beyond, whereby the leather diaphragm is raised and electric contact made. Two dry cells give the necessary current. A small electro-magnet of a few ohms resistance actuates the armature, an arm upon which pushes a ratchet-wheel one tooth ahead at every contact. This wheel has 120 teeth, and on its axis is a spiral cam with a slot. Against the cam rests the arm of the recording pen, so that as the cam revolves this arm is slowly moved latterly until at a complete revolution of the cam, that is, of 120 recorded waves, the arm falls back to its zero. On the recording tape, which is 1½-inches wide, two pens record; the one for the waves, the other (at the edge of the tape) the time-scale, given by a half-seconds pendulum clock within the case. The clock records every hour at intervals on the tape of 6 cm. The wave record is a very finely serrated oblique line, the inclination of the line (120

waves) being dependent upon the period of the waves. If for instance the period is 6s, then each line would represent a duration of 720s or twelve minutes, and during the hour there would be exactly five such lines. The paper roll is renewed once a week. Before deciding on the size of pipe to use at Chebucto, and testing the sensitiveness of the diaphragm, *i. e.*, how quickly it responds to change of pressure, a garden hose of measured length was coupled to the diaphragm stand and the other end secured to a straight rod about nine feet long. A sounder and dry cell were connected with the diaphragm, and then the hose with rod vertically immersed into the open reservoir near the light-house until an electric contact by the diaphragm was affected; the depth immersed was noted. The experiment was repeated several times very satisfactorily, and it was found that a quarter of a pound of atmospheric pressure was ample for obtaining contact. The greater diameter of the sea-end was taken so as to prevent as much as possible clogging by sea-weeds, which besides are held in check by a cage covering the end of the pipe. It is obvious that the diaphragm cell must be provided with a "leak", otherwise, even were there no waves at all, the slowly rising tide, which by the way is here about six feet, would compress the air and make contact, and the circuit would remain closed for hours and waste battery. It is found that with the proportion of pipe used, the leak, which is adjustable, may be given pretty wide latitude; for with the present clean pipe there is pressure to spare, and the leak does not militate in the least against the rapid action of the waves.

The sea-end of the pipe gives the most anxiety, as it has to resist the immense force of the waves during storms. The undagragh is now in satisfactory operation but the sea-end has yet to be permanently secured and this will be done by encasing it in an iron girder, the whole imbedded in about four tons of cement for some forty feet in the sea.

The whole subject of microseisms is so new that we have to feel our way in this investigation. Here in Ottawa, three hundred miles from the nearest sea-coast, we have in a general way

correlated microseisms recorded by the seismograph with the storms along the Atlantic coast from Cape Hatteras to St. John's, Newfoundland, a distance of 1500 miles, so that for an exhaustive study a number of undagraphs should be installed. However a beginning has been made at Chebucto, distant in an air-line about 620 miles from Ottawa; and the results will be published as soon as available. Not only to the layman does it seem extraordinary that the action of the disturbed ocean near the sea-coast should travel as tremors through the earth, whether as the result of the pounding of the waves on the shore or of the rhythmic loading of the sea-bottom by the waves, hundreds of miles inland to record themselves by means of the sensitive seismograph.

The accompanying photographs are self-explanatory. The one (Plate XVI.,) shows the whole apparatus ; the tripod stand contains the diaphragm and shows where the pipe is connected ; and the other photograph (Plate XVI.,) shows the mechanism more in detail, without the paper on or the lower roll, on which it is wound up by the action of the weight. The rocky nature of shore-line where the pipe is laid, is shown on the photograph of Chebucto Head. (Plate XVII.).

Dominion Observatory,
Ottawa, Canada,
September 12, 1913.

THE SOLAR UNION

By J. S. Plaskett

THE fifth meeting of the International Union for Co-operation in Solar Research was held at Bonn, July 30 to August 5. At the previous meeting at Mt. Wilson in 1910, the invitation of Professors Kayser and Küstner to hold the next conference at Bonn was accepted. I feel sure that every member who was present at Bonn is fully convinced that the choice was a wise one and is delighted that he was able to attend this meeting, one of the best managed and most interesting and pleasant congresses ever held.

Bonn is a charming university town, beautifully situated at the entrance to the finest scenery on the Rhine, and is eminently suited for a meeting of the Solar Union. It has the good fortune to have within its borders in the first place the new Physical Institute of the University of Bonn, presided over by Professor Kayser, certainly the best known figure in the spectroscopy of to-day, representing the physical and astrophysical side of solar reseach ; and in the second place the Observatory of Bonn, celebrated for the work of Argelander, and which is now most ably directed by Professor Küstner one of our most eminent astronomers, representing the astronomical side of the problems of the sun's constitution.

Professors Kayser and Küstner had a difficult task, after the precedent set by the Mt. Wilson conference, and considering the advantages for a solar conference of an observatory especially instituted for solar research and magnificently equipped with every appliance for its purpose, to arrange as interesting a programme. That they succeeded in the most admirable manner and that the fifth conference was one of the most successful and enjoyable not only in the value and interest of the work accomplished but also in the social side of the gathering, which was

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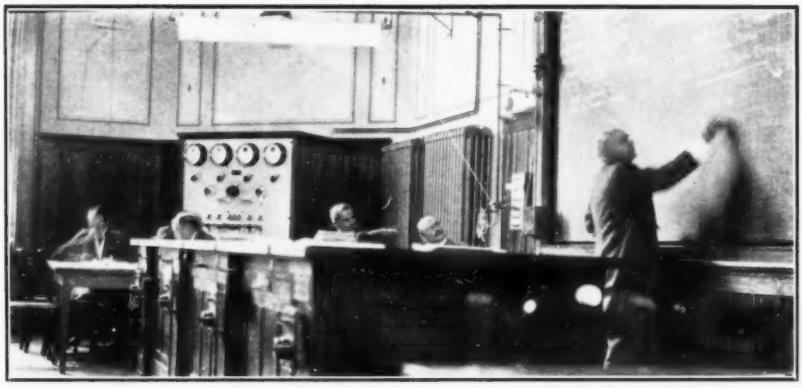


De la Baume Pluvinel Konen Turner Pringsheim St. John

AT THE MEETING IN THE LECTURE ROOM OF THE PHYSICAL INSTITUTE.—LAST SESSION

Haussmann Weiss Schlesinger Russell Pickering Campbell

WAITING FOR THE CAR, POPPALSDORFER ALLEE

specially emphasized, will be admitted by all present. As a full account of the proceedings will be published in the volume of the *Union* dealing with this meeting, I shall not attempt to give a detailed account of the scientific results obtained but rather to present a general impression of the whole, both scientific and social.

The opening event on the programme was a reception given by the city of Bonn to the delegates and guests of the Solar Union on the evening of Wednesday, July 30. Most of the latter arrived during the late afternoon and evening, and many proposed to dine before going to the reception, at which, according to our ideas, only light refreshments would likely be served. But the German idea of hospitality is much more elaborate and generous than ours and we were advised that dining was not necessary. This advice we found to be well founded for, after shaking hands with the oberbürgermeister and his wife, and chatting with friends for a few minutes we were conducted to beautifully decorated tables and served with an elaborate banquet, all kinds of good things to eat and varieties of wines to drink. The conduct of a banquet in Germany is different from Canadian custom in distributing the speeches between the courses instead of having them all grouped together at the end. As the interval between courses is much longer than with us, this is a much better arrangement, especially to those having to speak, for if their talk comes early they still have a chance of enjoying part of their dinner. A charming speech of welcome by the mayor and short replies in German, French and English were thus pleasantly distributed between the courses. During the intervals when no speeches were being given, time was pleasantly passed in making acquaintance with one's neighbors. After the banquet, half an hour was spent in social talk and renewing of acquaintance until the breaking up, which took place at a reasonably early hour: truly an exceedingly pleasant and well managed affair and an ideal way of opening a scientific gathering. For everybody agrees that all such meetings are most valuable in the chances they give of becoming acquainted with, and informally

discussing one's work with those interested in similar work, or those working along allied lines.

The formal business of the Union was opened the following morning, Thursday, at 10 o'clock in the large lecture room of the Physical Institute, by the reading of the report of the Executive Committee. In the regretted absence of the Chairman, Professor Schuster, who has so ably conducted the previous conferences, the chair was taken and the report read by Professor Turner. It dealt, in a brief way, after reference to the loss by death of several members, with formal notices of the election of Professor Belopolsky to the Executive Committee, and of the Académie Royale des Sciences des Lettres et des Beaux Arts de Belgique as one of the Societies of the Union; with proposals in regard to the method of observing and recording solar prominences; and with a statement in regard to the cost of printing the last volume, and a recommendation to consider means of meeting the deficits that have occurred (over £50 on the last volume) which have been generously met by Professor Schuster in the past. In this connection, it may be as well to say that it is proposed at the next meeting to so change the constitution as to enable a subscription of £1 per member to be charged for each meeting.

In the reading of the announcements in regard to the various excursions and entertainments which had been arranged Professor Kayser drew the attention of the meeting to a Zeppelin military dirigible flying towards the Institute, which the authorities had sent at his request from Cologne. The meeting temporarily adjourned while everyone went out to see the enormous airship sailing overhead, circling around and returning to Cologne.

The first report presented was that of the Computing Bureau by its chairman Professor Turner. After speaking of the work done by the Bureau with the limited means at its disposal, he proposed that it be turned over to Cambridge, to which the Solar Physics Observatory has recently been removed, but the sense of the meeting was unanimous for Professor Turner to keep on with the work for the present.

The report of the Committee on Solar Radiation, one of the most important committees of the Union, was then read by its Chairman and principal worker Professor Abbot. This report covers very fully all the work done since the last session in connection with the radiation intensity of the sun. It refers to the spread of pyrrheliometric observations, and to the standardization of the instruments employed, and incidentally in this connection to the remarkable decrease in intensity after the eruption of Mt. Katmai last year. It deals briefly with recent results obtained in atmospheric transmission which agree well with earlier values, so that it is considered that the tranmission is now well determined. It recommends that observation of the intensity of sky light and of the nocturnal radiation of bodies on the earth be carried on. The report deals fully with the recent work done, principally by Professor Abbot himself, in the determination of the solar constant. It records the establishment of and results obtained from the subsidiary station of the Smithsonian Institution in Algeria which was established by the United States Government, mainly on account of representations made by the Solar Union and some of the individual members. The values obtained at Mt. Wilson and in Algeria were, considering circumstances, in general in such good agreement that Professor Abbot feels that the results reported at the last session are confirmed. The results of the three years work on the solar radiation may probably best be summarized in the words of the Committee.

"In view of what has been reported the Committee feels that the period which has elapsed since the last meeting of the Solar Union has been very productive in the results on the quantity and effects of the solar radiation. In brief: The standard scale of radiation seems to be closely fixed; the mean value of the solar constant of radiation is apparently well determined (1·932 calories); the variation of the quantity of solar radiation in association with the sun-spot numbers appears to be strongly indicated (increase of radiation with increase of sun-spots and the curious result of, at the same time, lower temperature of the earth); a short irregular periodicity of the sun seems

to be established ; and much valuable work in connection with the distribution of radiation at different parts of the earth's surface, the measurement of the light of the sky and of nocturnal radiation, and on the connection between solar radiation and meteorology has made substantial progress." The parts in parenthesis are interpolated.

The report was discussed by Schwarzschild, Julius and Turner and an interesting communication from Evershed was read by Fowler in which it was proposed to determine the variation in the light of the sun by measuring the variation in the light of the moon and planets.

The meeting adjourned for luncheon which was held at the Hotel Royal in common. Luncheon and indeed all meals in Germany are a much more important and solemn function than with us and take at least twice the time. It was of course very agreeable during this meeting, as the long intervals between courses gave good opportunities of becoming acquainted and for informal discussions.

The afternoon was spent in the meeting of the various committees to discuss and revise their reports for presentation at future sessions and two committees, of which I was a member, the Committee on Spectral Classification and on the Solar Rotation held meetings. The former meeting was quite unanimous and soon finished the business but in the latter there was considerable discussion and definite conclusions were not reached until later meetings.

Most of the evening was spent at dinner, chiefly notable for the difficulty in getting salt and water. The waiters at the Hotel Royal will probably vividly remember the party of English speaking visitors by their wish to have at least one salt cellar at a table and by their curious and apparently quite unprecedented desire to drink plain, cold, fresh, (some of the adjectives used to make them understand) water when so many other more desirable liquids were available.

The second day's session, after the preliminary announcements, was begun by the presentation of the report of the Com-

PLATE XX.

GROUP AT THE PHYSICAL INSTITUTE

GOING TO THE GARDEN PARTY, BONN OBSERVATORY, FRIDAY, AUGUST 1

mittee on Wave Lengths, perhaps the most important of the Solar Union. This report was read by the chairman, Professor Kayser, and recorded very material progress in all regards since last meeting. It is rather difficult to summarize the many important points dealt with in this report and in the discussions following, and this statement must be taken as expressing my own recollection and interpretation of the features of the report and the discussion thereon. It will be remembered that at the Mt. Wilson meeting very substantial progress was made in adopting standard wave lengths of the second order. These wave lengths were the means of three independent and yet very closely agreeing observations by the interferometer method, of the wave lengths of a number of lines of the iron arc, about 50 Angstroms apart, between λ 4282 and λ 6494.

It was proposed to extend these interferometer measures towards the red and violet and to obtain tertiary standards by interpolation from grating spectra.

Work done in continuation of this programme showed for a time some curious and disconcerting discrepancies not only in the tertiary standards but doubt was also cast upon the accuracy of some of the secondary standards. Further work by St. John and Ware and by Goos showed that the difficulty was, in all probability, caused by the character and properties of some of the iron lines measured, that not all lines were suitable for standards. it was found at Mt. Wilson that some of the lines gave markedly different values at Pasadena and on the mountain, evidently due to difference of pressure. From this and previous work the iron lines were divided into different divisions *a* to *c* according to their behavior under pressure and only the first two or three divisions were considered suitable for standards.

Goos showed further that the wave lengths of many of the lines varied with the length of and position in the arc and the strength of the current. This he attributes to varying pressures in the arc but Kayser thinks it is more likely due to unsymmetrical broadening.

These results have much cleared the air and explained many

of the puzzling results secured. The accuracy of the adopted secondary standards is confirmed and further secondary standards outside the previous limits *i. e.*, from λ 4280 — λ 2373 and from λ 6494 — λ 8000 have been measured by interferometer methods, but, as many of these have only been obtained by one observer, they have not yet been adopted. The lines that can safely be used as standards and the conditions in the arc were laid down by the committee and are briefly as follows: Lines of groups *a*, *b* and *c* according to the Mt. Wilson classification only to be used. The electrodes are to consist of iron rods 7 mm. in diameter; a direct current at a potential of 220 volts is to be used; 6 amps. for lines whose wave length is greater than λ 4000 and 4 amperes when less than λ 4000; the length of the arc is to be 6 mm., the positive pole to be above and the part of the arc near the positive pole to be used. In group *c* lines, the slit is to be placed at right angles to the arc and the direction of the current is to be frequently reversed.

The report was discussed by Buisson, Hartmann, Konen, Schwarzschild, Hemsalech, St. John and Kayser and was adopted.

The Report of the Committee on the Classification of Stellar Spectra was then read by the chairman Professor Pickering. The work of the committee had consisted in obtaining from all its members and other astrophysicists and astronomers answers to questions as to the best system of classification. The tenor of the replies to these questions was nearly unanimous in favor of the Draper classification, but the general feeling was opposed to the adoption of any system as a permanent one. There was some discussion in committee as to the advisability of incorporating some symbol to indicate the width of lines, but in the absence of data from slit spectrographs in this connection (the width of lines from objective prism spectrographs depending on conditions of seeing, focus, temperature, etc.), consideration of this question was deferred until further data were available.

The following resolutions for adoption by the Solar Union were proposed by the committee:

"That the committee on the classification of Stellar Spectra be asked to secure by co-operation the material necessary for the establishment of a system that can be recommended for universal adoption: and, that pending the establishment of such a system the use of the Draper classification be recommended in the form described in volume 56, page 66, of the *Annals* of the Harvard College Observatory: except that hereafter in accurate classification a zero be added to letters not followed by other numerals, and that the absence of any numeral be taken to indicate only a rough classification." These resolutions which apparently were entirely in accord with the sentiment of the Union were adopted without discussion. M. Deslandres then gave an interesting description of his recent spectroheliographic work. As such good progress had been made with reports, no afternoon session was held and the members amused themselves in various ways until six o'clock, when, at the invitation of Professor and Mrs. Küstner all attended a reception and garden party at the Bonn Observatory. The beautiful grounds of the Observatory were tastefully decorated and the guests were made to feel entirely at home by the host and his charming wife and daughters. After refreshment an invitation was given to all to inspect the Observatory and members of the staff were on hand to explain the different instruments. The instrument with which Argelander made his observations for the Durchmusterung and his original note books naturally excited much interest, but the Astrographic telescope and the meridian circle also came in for their share of attention and every one was much interested in seeing an institution which with a comparatively modest equipment has done such splendid work. After the inspection an exceedingly pleasant two hours was spent in friendly chatting in the garden where a supper had been laid. The feeling of the guests towards Professor and Mrs. Küstner for their delightful entertainment were well expressed by Professor Turner in a short speech and by the singing by the English speaking contingent of "They are Jolly Good Fellows."

The third day's session opened with the announcements of

the various arrangements that had been made for the entertainment of the members, which occupied nearly an hour's time, and this was followed by the formal business of the morning, the reading and discussing of the report of the Spectroheliograph Committee which was presented in English by Slocum, in French by Chrétien and in German by Konen. This report suggested that comparison of the results from different types of spectroheliograms made by instruments of varied form and dispersive power be made: that spectroheliographs of high dispersion capable of recording the details of the higher atmosphere be installed wherever possible: that the "spectro-enregisteur des vitesses" for radial velocities be recommended for use especially with the hydrogen and calcuim lines: it recommended that several observatories now possessing spectroheliographs be added to the list and expressed its gratification that the memorial to Seechi was likely to take the form of a tower telescope. The proposal in this report to unite the Prominence and Spectroheliograph Committees into one with the title of the Committee on the Solar Atmosphere caused a great deal of animated discussion taken part in by Schwarzschild, St. John, Slocum, Chrétien, Donitch, Butler, Kempf, Ascarza and Abbot. The matter was left in abeyance until the presentation of the report of the Committee on Solar Prominences. This report dealt with the adoption of standard methods in the observation and particularly in the recording and tabulating of prominences which had hitherto been quite unsystematized. It defined the limiting sizes and heights of prominences to be recorded, the units of area adopted and the method of defining the positions. The question of the union of these two committees into a Committee on the Solar Atmosphere composed of two sub-committees, one dealing with visual and the other with photographic observations was then brought forward and warmly debated pro and con by nearly every member of the committees and by others as well, but was finally settled by the decision of a large majority of the delegates in favor of the union of the committees.

Störmer then gave a very interesting paper on Auroræ and

Magnetic Whirls, showing some remarkable photographs and stereographs of auroræ and after a short talk by Hemsalech the session adjourned.

In the afternoon, under guidance of Professors Kayser, Konen and Pflüger, one of the excursions, that to Cologne, took place. The party travelled in a special electric train to Cologne, were shown through the Cathedral, probably the finest example of Gothic architecture extant, the magnificent bridge over the Rhine and the museum containing some noted paintings. At eight o'clock the party were received by the oberbürgermeister and his wife in the Gürzenich, a beautiful building of the 15th century, used only for royal and state functions, and were banqueted by the city of Cologne in the grandest style in the banquet chamber, a magnificent hall with fine mural paintings of mediæval German history. Everyone felt, I think, that his was the most impressive function of all the entertainments provided, and returned to Bonn delighted with the hospitality of Cologne and with the arrangements which had rendered it possible.

For the Sunday August 3, two excursions had been planned, a walking trip in the Siebengebirge for, according to the programme, "die wanderlustigen jüngeren Herren", and an automobile tour through the Eifel to the valley of the Mosel, thence to Coblenz and back along the Rhine to Bonn for "die Damen and älteren Herren." I don't know whether my choice of the motor trip puts me in the latter class but even if so it was well worth the appellation. A ride of 150 miles over the best of roads and through, perhaps the most beautiful, and certainly in a historical and legendary sense, the most interesting scenery in Germany is well worth being classed with the older men. I understand the walking tour was also very enjoyable although naturally not covering so much country. This and all the excursions and entertainments were made much pleasanter by the ideal weather which favored us throughout the meetings.

Monday saw the business of the Union resumed, after votes of thanks to the authorities of Cologne and to those who had provided the machines for the auto tour, by the presenting of the

Report of the Committee on the Solar Rotation by the writer, who, in the absence of the chairman Professor Dunér, was appointed acting chairman. The committee had held several meetings and were unanimously of the opinion, owing to large differences in the value of the rotation obtained by different observers, a difference of 10 per cent between the highest and lowest, that it would be unwise to continue the work along the same lines until the cause of these differences had been determined and removed. It was generally felt that the causes of these differences were mostly of an instrumental character and were likely partly due also, to personal equation in measurement, and that they were not to be ascribed to any change in the velocity of rotation of the sun. The report recorded the measurements that had been published since the Mt. Wilson meeting and discussed the various points of difference which these measurements showed, this discussion leading to the following resolutions recommended by the committee for adoption.

"1. It is highly desirable to trace to their source the systematic differences that are found in the value of the solar rotation by different observers and this investigation should take precedence of a continuation of the programme adopted in 1910.

2. For this purpose study should be directed to determining the velocity at the solar equator by as many different methods as possible, and it is recommended that the ten lines chosen in 1910 in the region λ 4220 – λ 4280 be used for this purpose.

3. That investigation should also be made into the personal differences that are found in measures of the same plate by different observers."

These recommendations were adopted by the Union without discussion.

The Report of the Committee on Sun-Spot Spectra was read by Professor Fowler, its energetic Secretary, and gave a resume of the main results arrived at from the last three years' observations. They agree in confirming the practical unchangeableness of the spectrum of sun-spots as testified to by both visual and photographic methods. The Committee recommended that the visual

observations be continued for the next three years, and that the photographic observations be extended if possible, the spectrum to be divided between the different observers. For this purpose the writer was added to this committee.

The report and recommendations were adopted by the Union also without discussion.

The report of the Solar Eclipse Committee was presented by Comte de la Baume Pluvinel and gave an account of the results of recent observations of eclipses. Data concerning the Russian Eclipse of next year were given by the Count who was followed by M. Donitch with further information and offers of assistance to all who proposed to observe this eclipse.

This report was adopted by the Union and finished the committee part of the business.

Duffield spoke to a resolution in favor of establishing a solar observatory in Australia and gave a history of the progress of the scheme. The recent changes in the Government of the Commonwealth have hindered the beginning of the work but it is thought that it will likely be started in the near future.

After a short talk by Hemsalech on observations of enhanced lines, Professor Pickering proposed rules for the conduct of committees with the purpose of facilitating the conduct of business. The proposal was endorsed by Kayser but further discussion was postponed until the morrow, to allow Professor Julius to give a paper and show experiments on the artificial production of sun-spots.

The afternoon was spent by the members in various ways while the evening was devoted to a conversazione at the Physical Institute where, not only were numerous experimental demonstrations given, but opportunity was afforded members to show examples of their work. It was a most interesting and useful entertainment. The Institute itself had only been completed three months and is hence the last word in the design of a modern physical laboratory. I had the privilege of being conducted by Professor Kayser through his spectroscopic laboratories where every convenience for spectroscopic research is available. The

concave gratings are mounted differently to the usual form, the grating and camera being placed at the two ends of a massive beam which forms the diameter of a semicircular beam on which the slit is moved. Evidently the geometrical requisites are fulfilled by this form equally well with Rowland's, and it has the advantage of being readily made light tight without requiring the room to be darkened, and of not requiring so much space as the usual form.

The most spectacular demonstration was that of the new molecular exhaust pump, which will bring a tube to the Roentgen vacuum in about a minute. This process was shown in the lecture room. It was exceedingly interesting, and very beautiful as well, to see a tube about six feet long with terminals at the end go so rapidly through all the stages of discharge from the stream of sparks to the Roentgen fluorescence.

The most interesting of the astronomical displays were the slides of nebular spectra exhibited by Max Wolf from exposures of 24 hours and upwards. The ring nebula in Lyra showed rings of different diameters and shapes for the different monochromatic radiations, while the Andromeda Nebula showed very plainly the solar type absorption spectrum in the violet from *G* to *K* and in the blue a number of emission lines or bands indicating apparently, in addition to its stellar composition, the presence of gaseous material.

The final meeting of the Union was held on the Tuesday morning, August 5. Professor St. John presented a short communication in regard to some recent work on the motions of the vapors in sun-spots, showing that there appears to be differentiation or sorting out, even among the vapors of any one element such as iron. Some of the spectral lines of iron for example show large positive motions while others are nearly at rest and a few have negative motions. He also read a statement from Professor Hale in regard to the most recent developments in the study of the general magnetic field of the sun.

The proposal in regard to contributions from the members

was necessarily deferred, owing to constitutional difficulties, for action until the next session.

The membership of all the committees of the Union was revised by adding as new members those who had shown interest or done work in line with the objects of the various committees, while some names, not enough I think, of those who had never nor were likely to help in the work were left off.

The question of the place of the next meeting was decided in favor of Rome, while an invitation for a meeting to be held in 1920, the centenary of the Royal Astronomical Society, at Cambridge was voiced by Professors Hills and Stratton.

The formal resolution in favor of a solar observatory in Australia was proposed by Professors Campbell and Abbot while Pickering's proposal in regard to the conduct of committees was recommended by the Union. Abbot had a proposal along similar lines to ensure the preparation of committee reports in time, while Campbell proposed that the chairman of the executive committee, in case of remissness in the chairman of any committee of the Union, be empowered to appoint an acting chairman.

The votes of thanks to those responsible for the arrangement and carrying out of the meetings and entertainments were most enthusiastically received and passed, evincing the strong feeling among all the members of gratitude for the splendid arrangements.

Professor Sampson voiced very neatly and gracefully the feeling of the English-speaking members for the great courtesy, kindness, and thoughtfulness of the Germans in not insisting, as was their due, on the discussions taking place in German and furthermore for their goodness in translating every announcement and important piece of business into English. I am afraid that the same thing neither would nor could be done at a meeting held in an English-speaking country whose members rarely have speaking knowledge of any language but their own.

The fifth meeting of the International Union for Co-operation in Solar Research finished its business and adjourned before

one o'clock. I am convinced that everyone felt that it had been one of the most successful and useful in point of work accomplished as well as the best arranged and most enjoyable in the number and quality of the excursions and social re-unions provided. It had been planned and managed in the typically thorough German way, in a way which will long be remembered by those fortunate enough to be present.

But although the business of the meeting was finished we had by no means seen the last of our kind hosts. Professor Kayser had chartered one of the passenger boats of the Rhine and at four o'clock we all embarked and steamed some miles up the river. A delightful day, a beautiful sail and the kindliest and happiest spirit in every one made this afternoon and evening an ideal ending of a splendid meeting. It culminated in the banquet on board where the spontaneous enthusiasm and goodwill overflowed in speeches, in half a dozen languages, of thankfulness to our host and those who had helped to make our stay so pleasant.

If we could only have many such international gatherings as this more would probably be done to promote international friendliness and agreement than all the formal peace conferences ever held.

Even this was not the last kind office done for us. For those who were travelling to Hamburg to attend the meeting of the Astronomische Gesellschaft, arrangements had been made for a special sleeping car for the party of twenty and we were escorted to the station and put safely aboard by our kind entertainers.

From beginning to end the meeting was in every respect an unqualified success and I am very glad to have this opportunity of expressing not only my own gratitude and that of all the members with whom I talked but also I am sure of all members present for the perfect way in which the many arrangements for our comfort and entertainment were carried out.

Below is given the names of those attending the meeting as delegates and guests.

Professor C. G. Abbot, Washington, U. S. A.

Miss L. B. Allen, Wellesley, Mass., U. S. A., Assistant in the Observatory.

Professor J. S. Ames, Baltimore, U. S. A.

Professor V. F. Ascarza, Madrid, Director of the Observatory.

Professor O. Backlund, Pulkowa, Russia, Director of the Observatory.

Professor S. I. Bailey, Cambridge, U. S. A., Observatory.

Professor Baillaud, Paris, Director of the Observatory.

Professor Baillaud, (fils), Paris, France.

Professor Belopolsky, Pulkowa, Russia.

Professor van Biesbroeck, Uccle, Belgium

Professor F. Blumbach

Dr. Bosler, Paris, Observatory.

Professor Buisson, Marseilles.

Dr. K. Burns, Washington, U. S. A.

Dr. A. A. Buss, Manchester.

Professor Butler, Cambridge, England.

Professor Campbell, Mt. Hamilton, U. S. A., Director of the Lick Observatory.

Miss Cannon, Cambridge, U. S. A., Assistant in the Observatory; and sister, Mrs. Marshall.

Professor Chetien, Nice Observatory; and wife.

Father A. Cortie, Blackburn, England.

Professor A. Cotton, Paris.

F. Croze, Paris.

Professor H. Deslandres, Paris, Director of the Astrophysical Observatory.

Dr. N. Donitch and wife.

Professor C. L. Doolittle and wife, Philadelphia, U. S. A.

Professor F. W. Dyson, Greenwich, England, Astronomer Royal.

Professor G. Eberhard, Potsdam, Astrophysical Observatory.

Professor A. S. Eddington, Cambridge, England.

Professor Eversheim, Bonn.

Professsor Fayet, Nice, Director of the Observatory.

Professor A. Fowler, London.

Dr. Furuhjelm, Helsingfors, Observatory.

Prince B. Galitzin, St. Petersburg.

Dr. H. Giebler, Bonn.

Dr. C. H. Gingrich, Northfield, Minn., U. S. A.

Dipl.-Ing. L. C. Glaser, Berlin.

Dr. Goos, Hamburg.

Dr. L. Grebe, Bonn.

I. G. Hagen, S.J., Rome.

Professor L. Hartmann, Gottingen, Director of the Observatory.

Professor Haussmann, Aachen.

Mrs. Hastings, Cambridge, U. S. A.

D. E. A. Hemsalech, Paris.

Professor E. Hertsprung, Potsdam, Astrophysical Observatory; and wife.

Professor J. Hepperger, Vienna, Director of the Observatory.

Major E. Hills, London, President of R. A. S.; and wife and daughter.

Dr. O. Holtz, Bonn.

J. Hopmann.

Mr. J. B. Hubrecht, Knutsford, England.

Dr. L. Janicki and wife, Physical-Technical Reichsanstalt.

Professor W. H. Julius, Utrecht, Holland.

Professor H. Kayser, Physical Institute, Bonn.

Professor P. Kempf, Potsdam, Astrophysical Observatory.

Professor H. Konen, Munster in W.

Geh. Rat Professor Küstner, Bonn; and wife.

Professor H. Ludendorff, Potsdam, Astrophysical Observatory.

Professor W. Michelson, Moscow.

Professor E. L. Nichols, Ithaca, U. S. A.; and wife.

Professor Nicholson, Cambridge, England.

Dr. F. Nierhaff, Bonn.

Baron v. d. Pahlen, Caputh near Potsdam; and wife.

Professor Parkhurst, Williams Bay, U. S. A., Yerkes Observatory; and wife and neice.

Professor Paschen, Tübingen.

Professor A. Pflüger and wife, Bonn.

Professor E. C. Pickering, Cambridge, U. S. A., Director of the Observatory.

Mrs. W. H. Pickering, Cambridge, U. S. A.

Dr. van den Plaats, Utrecht, Holland.

Dr. J. S. Plaskett, Ottawa, Canada, Observatory; and wife.

Professor Plummer, Dublin, Director of the Observatory.

Professor E. Pringsheim, Breslau.

Professor A. Ricco, Catania, Director of the Observatory.

Professor G. B. Rizzo, Messina, Director of the Observatory; and wife.

Geh.-Rat Professor C. Runge, Gottingen.

Professor H. N. Russell, Princeton, U. S. A.; and aunt, Miss A. Norris.

Professor P. Salet, Paris.

Professor R. Sampson, Edinburgh, Astronomer Royal of Scotland.

Professor F. Schlesinger, Allegheny, U. S. A., Director of the Observatory; and wife.

Geh. Rat Professor Schwarzchild, Potsdam, Director of the Astrophysical Observatory.

Küstner Julius Buisson Burns Eversheim Backlund

THE GARDEN PARTY AT KÜSTNER'S

Kayser Pickering

AFTER LUNCH, SUNDAY, AUGUST 3

Professor H. Knox Shaw, Helwan, Egypt.
Professor F. Slocum, Williams Bay, U. S. A., Yerkes Observatory; and wife.
Professor C. E. St. John, Pasadena, U. S. A., Mt. Wilson Observatory.
Professor C. Störmer, Christiania; and wife.
Professor Stratton, Cambridge, England.
Professor E. Strömgren.
Professor P. Stroobant, Brussels; and wife.
Professor H. H. Turner, Oxford, England, Director of the Observatory.
Geh.-Rat Professor W. Voight, Göttingen.
Mr. C. de Watteville, Paris.
Professor E. Weiss, Vienna; and daughter.
M. E. T. Whitelow, Southport, England.
Miss S. F. Whiting, Wellesley, U. S. A., Director of the Observatory.
Professor M. Wolf, Heidelberg, Director of the Observatory.
Dr. W. Zurhellen, Berlin.

I wish also here to express my deep obligation to Dr. King for the privilege and honor of representing the Dominion Observatory at this memorable meeting.

DOMINION OBSERVATORY,
OTTAWA, CANADA.
September, 1913.

FURTHER INFORMATION REGARDING THE METEORIC DISPLAY OF FEBRUARY 9, 1913.

By C. A. Chant.

ELSEWHERE in this issue is a discussion of this remarkable phenomenon by Mr. W. F. Denning, F.R.A.S., of Bristol, England; and since it was put in type fresh information has been received from two sources.

In my original paper one of the most interesting of the observers' reports printed was by Colonel W. R. Winter, of Bermuda. He has been able to collect additional facts, and has embodied them in a letter dated November 24, which I give in full below. Another discussion of the display appears in the *Journal* of the British Astronomical Association, written by Rev. M. Davidson, B.A., B.Sc., F.R.A.S., a well-known English authority on these subjects; and Mr. Denning has forwarded to me a synopsis of this paper. It deals chiefly with mathematical calculations of the path of the bodies, and is printed immediately after Colonel Winter's communication. Following this, I offer some remarks on these two papers.

MORE NEWS OF THE METEORS FROM BERMUDA

By W. R. Winter

[A LETTER TO THE EDITOR]

I and many others have read with much interest the reports in your article in the Journal and especially your review of them and your deductions. I have been able through this to get more information and give a general average of the opinions formed below:—

Appearance of the Display. The display came in sight in the north-western sky and, to the observers south of Hamilton, appeared to pass over or near the Bermuda Cathedral and cross the Island to the south of south-east. To me it appeared to come

over the Cathedral and to disappear behind the crest of Milford Hill. This would give a parallel to its track.

When first seen it was taken for a display of two arc lights at the electric station which lies behind the Cathedral.

When these two leading bodies came to a point opposite the observer's station it was noted that they were flaking or emitting sparks which accompanied them, but did not form the larger trailers which followed, which resembled sky rockets in appearance ; these were apparently formed by explosions, one of which occurred in Bermuda and was witnessed by Mr. F. Goodwin Gosling and Mr. R. Ingham.

It is agreed that the general appearance of the display differed materially from the reports of most of the observers in Ontario. Most of the large leading bodies had disappeared and the number of trailers and groups had greatly increased. These groups in some instances were very large and spread from 30° to 50° towards the zenith, they were connected by stragglers singly and in pairs. As they dropped behind they shortened in length and became more red in appearance until the last were mere red specks with a bluish flame-like appearance above them ; they also appeared to have lost their energy and to resemble wind driven pieces of burning brown paper.

The two leading bodies were very brilliant and resembled arc lights and I observe that very few noticed this ; Mr. W. H. Stevenson of Fenelon Falls, is one of the exceptions.

Time taken in passing. I regret that no one timed these objects in passing. Mr. Goodwin Gosling, having watched the leaders pass out of view behind the trees, had time to go into the house, upstairs and to call others and even then a steady stream was coming from the north-west sky, and it was a considerable time before all had passed. Two minutes seems a low estimate of the time in which they appeared to sail slowly and majestically across the sky.

Height above horizon. The various angles are very conflicting but there is no doubt that they were 30° from the horizon, at least. Mr. Goodwin Gosling's angle was carefully taken in

regard to the tops of two tall trees, one behind the other, the farther one slightly the lower. The leaders passed this gap as shown in sketch. The lower one level with top of taller tree 55

METEORS AS SEEN IN BERMUDA

feet above the height of the eye, and 93 feet base line, giving an angle of about 30°.

Distance from Bermuda. We are agreed that these were much nearer than 131 miles and considerably over 26 miles high. The Royal Mail Steam Liner *Arcadian* arrived in Bermuda on the 10th February and must have come a course almost parallel to the display; it would be worth while writing the captain about it, the watch must have seen it.

Think you will agree with me in the supposition that the trailers had no origin separate from the main bodies and that certainly the whole of them which passed these Islands were off shoots from the leader's or from leaders which had disintegrated before reaching here.

I base this opinion on the following points:—two leaders only reached Bermuda; the number of trailers was enormously increased, whereas from the fact the tail end was observed all

along the line to be dying out they should have decreased; explosions took place at intervals, one was witnessed in Bermuda, which threw off portions of the envelope which developed tails of sparks; the trailers near the large bodies had very long tails and the others gradually shortened up until they at last disappeared; the groups were in irregular intervals caused by the greater or less frequency of the explosions; the explosions and the increase in the number of trailers evidently account for the remainder of the large bodies seen in Ontario.

This display was unlike anything we have seen before and is not as far as I can find accounted for in any astronomical work. We shall be pleased to get any further information that is obtainable. The general behavior was more like that of semi-gaseous bodies than that of the ordinary aerolite.

THE AMERICAN METEOR DISPLAY OF FEBRUARY 9TH, 1913.

By M. Davidson

On reading the account of this remarkable phenomenon in the JOURNAL of the Royal Astronomical Society of Canada, I found it difficult to account for the very long flight, at least 2400 miles, in spite of atmospheric resistance. The motion must have been nearly horizonal; indeed, so perfect was the adjustment between the velocity of the bodies and the resistance of the atmosphere, that they appeared to describe an orbit about the earth's centre.

I have given a discussion of this problem in the *British Astronomical Journal* for November; a very brief summary of the results arrived at is given below.

As the velocity which would cause a body near the surface of the earth to describe a circular orbit is 4·93 miles a second, the bodies must have had a velocity near this. A greater velocity would imply an elliptic orbit, and they would rise from the surface of the earth; a less velocity would mean that they would slowly descend. I assumed a velocity of 5·15 miles a second when the

motion was parallel to the surface of the earth, and found that in describing half their journey, 1200 miles, with this velocity, they would rise 17 miles. If the velocity gradually fell from 5·15 to 4·93 miles a second, the latter being attained when half the journey was completed, the rise would be half of this, that is, 8·5 miles In traversing the second half of their path, I assumed that th velocity was gradually decreasing from 4·93 miles a second, the result being a slow drop towards the earth's surface of about 8 miles, this descent continuing until they were dissipated by the atmosphere or struck the sea farther on in their flight.

The next question to decide was that of the height above the surface of the earth. Using the most reliable results of atmoshperic resistance to the flight of projectiles, I found that a body of diameter 100 feet and of density about 6, would be required to start at a height of 34 miles, rising to about 43 miles towards the middle part of its flight, and then sinking as the velocity decreased from 4·93 miles a second. With bodies 10 feet in diameter, the figures are 45 miles and 54 miles; those intermediate in size would demand heights lying between 34 miles and 45 miles at the beginning. A flight much below 34 miles, even for the largest body, would be stopped by the resistance of the air before it could move 2400 miles, unless the velocity were considerably above 5 miles a second, and in that case it would rise very much from the earth's surface. An explanation of the ability of the various bodies to move so far may be found in the fact that they were at various heights, a fact attested by some of the observers; the smaller bodies which described the whole distance of 2400 miles or more were probably higher than the larger ones. Those which were not may have been amongst those described as "snuffed out". As atmospheric resistance increases relatively with a decrease in the diameter, it seems necessary to place the smaller ones which traversed the whole distance higher than those which were greater. Since a great number entered our atmosphere, there is every probability that some of these would be included amongst the fortunate ones which were of the requisite dimensions for their height to perform the long path.

I find it difficult to accept the upper limit of the estimate of their velocity given in the JOURNAL for May-June, 10 miles a second. The height given in one part, 26 miles, is not, I think, so near the truth as that given in another part, Table III, about 34 miles. Even this may be too low, and I am disposed to believe that they were much higher than this. Professor Chant has reduced the elevations by about one half, for reasons of which an explanation is given; without such reductions the height would be somewhere near 70 miles. It agrees more easily with the effects of atmospheric resistance to take an average height somewhere between 34 and 70 miles, probably near 45 miles.

It will be noted that Colonel Winter insists that the appearance of the display, at Bermuda was quite different from that when over Ontario. This was suggested to me on receiving Colonel Winters sketch, which was reproduced along with his report. In Ontario the bodies were arranged in distinct groups, while at Bermuda there were two brilliant ones leading a large number of bodies distributed fairly regularly in a long train behind. Many of the larger bodies may have broken up into smaller ones. From several places in Ontario observations of explosions and descriptions were reported.

The new evidence regarding the height of the meteors is interesting and important. To determine the height we must know, of course, the elevation above the horizon and the distance, from the observer, of the trace on the earth. Now the latter I think is the best determined feature of the phenomenon. Its location in central Ontairo is in error hardly more than or three miles, and I think it hardly more than ten miles out of its true position at Pense in Saskatchewan. A combination of these maximum errors would not make a change in the location of the easterly end of the observed path of more than 15 miles, that is the trace was not less than 116 miles from Bermuda. Of course, this assumes that the bodies were travelling over a great circle on the surface of the earth. Colonel Winter's new determination of the altitude is about 30½°, which, when cor-

rected for curvature of the earth, will be about 32°, and taking 131 miles as the distance of the trace the height deduced is 81 miles.

In view of the discussion which has arisen regarding the height, I have recently examined my data again, and the accompanying table embodies the results reached.

HEIGHT OF THE METEORS

Place	Dist. from Trace	Altitude Given	Red. 1/2	Cor. for Curv.	Height	Altitude Red. 1/3	Cor. for Curv.	Height
	miles	°	°	′	miles	°	′	miles
Aylmer	62	65	32½	23	41	43	53	60
Barrie	66	45	22½	27	28	30	57	39
Barrie	66	50	25	57	32	33	57	44
Brighton	97	30	15	23	28	20	23	38
Campbellford	111	<30	15	35	33	19	35	42
Campbellford	111	low	down					
Coboconk	106	20	10	31	21	13	31	28
Cobourg	81	45	22½	39	36	30	9	49
Coldwater	86	45	22½	44	38	30	14	52
Dresden	102	45	22½	59	45	30	29	62
Dutton	78	45	22½	37	34	30	7	47
Edgar	72	22½	11½	32	16	15	2	21
Elmvale	72	45	22½	32	32	30	2	43
Fenelon Falls	102	<45	21	27	42	28	27	57
Fullarton	30	67½	34	26	21	45	26	31
Georgetown	17	60	30	15	10	40	15	14
London	57	75	37½	19	45	50	49	70
Magnetawan	143	20	10	3	30	13	3	30
Milliken	42	50	25	36	20	33	36	28
Muncey	71	60	30	1	42	40	1	62
Painswick	64	30	15	55	19	20	55	24
Parry Sound	115	36	18	39	41	24	39	55
Petterlaw	72	75	37½	32	57	50	2	89
Peterborough	97	25	12½	53	24	17	23	32
Port Sidney	108	low	down					
Richard's Ldg.	82	67½	34	10	57	45	10	85
Rodney	93	45	22½	50	41	30	20	57
Sheridan	17	75	37½	45	13	50	15	20
Toronto	30	65	32½	56	20	43	26	29
Toronto	30	55	27½	56	16	37	26	23
Toronto	30	60	30	26	18	40	26	26
Trenton	104	30	15	29	31	20	29	41
Trout Creek	167	low	down					
Udora	73	45	22½	33	32	30	3	44
Warsaw	106	low	down					
		Average			31·1 miles			43·6 miles

When preparing my original paper the estimates of the altitude of the bodies seemed to be so discordant that I thought it better to depend on three particular observations which appeared to be especially worthy of confidence and which agreed closely with each other. These led to a height of 26 miles. Two or three other observers who reported to me personally and whom I questioned closely gave results a little higher but appearing to me to corroborate strongly my deduced result.

In dealing with the estimates of altitude made in the ordinary way, that is, without some definite method of measuring the angle, I reduced them, for reasons given in my paper, by about one-half. Mr. Denning states that he has found it more accurate to deduct one-third.

In the table I give all these ordinary estimates sent in with the exception of two, one of which was evidently too high and the other too low, and neither of which was made by the person who reported to me. In the first column is the name of the observer's station; in the second, its distance from the trace on the earth; in the third, the observer's estimate of the altitude; in the fourth, this estimate reduced by one-half; in the fifth, this reduced value corrected for the curvature of the earth; in the sixth, the height deduced from this corrected altitude; in the seventh, the original altitude reduced by one-third; in the eighth, this value corrected for curvature; and in the ninth, the height deduced from it. It will be seen that the heights vary between wide limits, the average of the 31 values being 31·1 miles in the first case and 43·6 miles in the second.

Both Mr. Denning and Mr. Davidson think my former estimate of 26 miles considerably too low, and though I have much hesitation in differing from their views I am inclined not to go far above this value. I would take the mean of 26, 31·1 and 43·6, or 34 miles, as a probable value.

It is true that this height is exceptionally low, but there are other exceptional features, too, — the general appearances, the length of path and the velocity. In the case of the great fireball of September 5, 1868, the length of the path was 1200 miles,

but the height at the beginning was 250 miles, at the end 85 and the velocity was 28 miles per second. Mr. Davidson shows that the larger the body the less may be the height, though for the largest body the height could not be much below 34 miles. I believe the bodies generally were more than 100 feet in diameter.

It occurred to me when considering Mr. Denning's paper that perhaps one reason why the bodies were so generally observed in Ontario was that they were nearest the earth then. Assuming, then, that the bodies moved in a conic section and that the perihelion was above the point where the trace cut the 80th meridian I proposed to determine the height the bodies would have when off Bermuda, 17° along in their path, taking different velocities at perihelion. This was done at my request by Mr. I. R. Pounder, B.A., of the University of Toronto. Assuming the distance from the earth's surface at perihelion to be 26 miles, the perihelion velocity for a body moving in a parabola to be 6·94 miles per second, and neglecting atmospheric resistance, the results came out as follows: —

Peri. Vel. in miles per. sec.	a miles	e	Ht. at Bermuda in miles
8·25	4792	1·8318	142
8	6020	1·6621	138
6·94	.....	1	115
6	7842	0·4917	84
5·8	6567	0·3030	76

Dr. R. K. Young, of Ottawa, using slightly different constants, obtained heights at Bermuda, in the first four cases, 146, 142, 118, 87 miles respectively. If we take the perihelion height as 34 miles, the heights at Bermuda would be increased about 8 miles.

From Colonel Winter's latest estimates of altitude the height at Bermuda is 81 miles, to produce which, on the above hypothesis a velocity of about 5·92 miles per second would be required. With a perihelion height of 34 miles the velocity

would be slightly under 5·8 miles per second. However, taking into account the atmospheric resistance the perihelion velocity must be somewhat greater, probably between 6 and 6·5 miles per second.

Acting on Colonel Winter's suggestion I have communicated with the company operating the S. S. *Arcadian*, and hope to hear from the captain in due time. Reports from steamships beyond the Bermudas at the time would be even more interesting.

A GREAT REFLECTOR FOR CANADA

By J. S. Plaskett

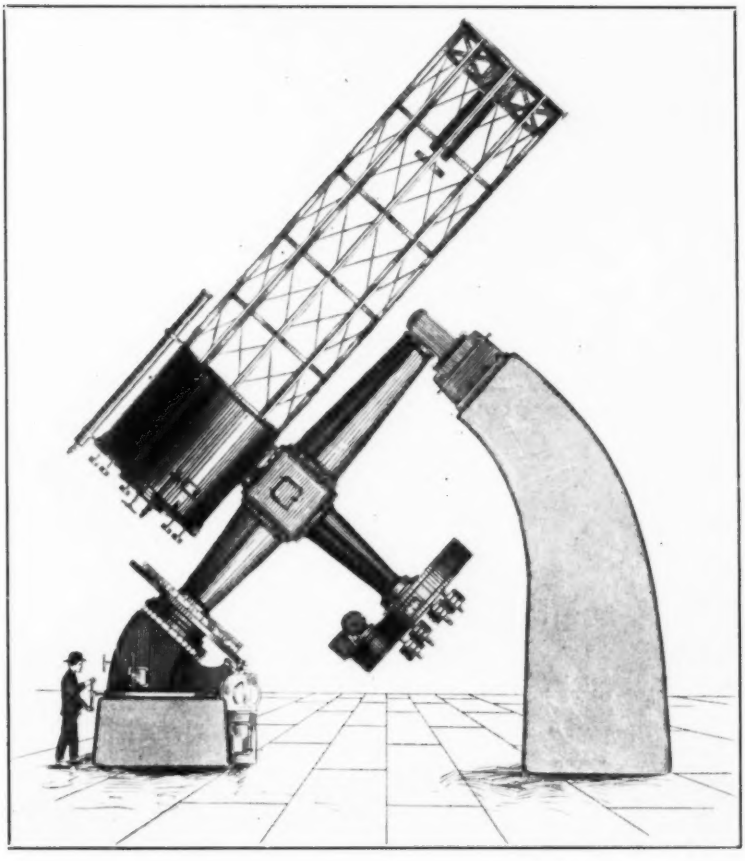
THE project for a great reflecting telescope of 72 inches aperture for the Dominion, a preliminary account of which was given in this JOURNAL*, has now crystallized into definite action as the contracts for the construction of the instrument have been awarded: to the J. A. Brashear Co., Pittsburg, for the mirrors and other optical parts; and to the Warner and Swasey Co., Cleveland, for the mounting.

Before describing the instrument it may be of interest to give a brief sketch of the initiation and carrying out of the project. Ever since the 15-inch refractor was put into active service, its limitations in the field of radial velocity observations, for which it has been chiefly employed, were recognized; and although they were minimized as far as possible by placing the optical systems of the telescope and spectrograph in the highest state of efficiency, so that the exposure times required were probably relatively lower than those of any other equipment, yet stars of the fifth magnitude are the practical limit attainable even with low dispersion.

The dream of the writer for a larger aperture was intensified at the fourth Solar Conference at Mt. Wilson in 1910. A meeting of a Committee of the Astronomical and Astrophysical Society of America on Co-operation in Radial Velocity Determinations, including among its members practically every one engaged in this work, was called by the chairman, Professor Campbell, during the Conference to consider a plan of co-operation in determining radial velocities of stars fainter than the fifth magnitude. The observation of the radial velocities of all stars brighter than the fifth magnitude had just been completed with a high degree

*This JOURNAL, Vol. VII., p. 217, May-June, 1913.

PLATE XXII.



THE NEW GREAT REFLECTOR FOR CANADA

Journal of the Royal Astronomical Society of Canada, 1915

of precision by Campbell himself at the Lick Observatory and this meeting was for the purpose of planning its continuation to fainter stars. Very little, however, was accomplished as no one considered the aperture of his telescope sufficiently large to successfully undertake this work.

This seemed to the writer to be such a splendid opportunity for Canada to take a prominent part in this exceedingly important work, one of the most pressing needs in present day astronomy, and to place herself in the forefront among the nations for her enterprise in promoting scientific research, that immediately on his return he placed the matter before the Chief Astronomer, Dr. W. F. King. Dr. King at once endorsed the plan heartily and has given throughout the negotiations his active and able backing, support, and advice, without which success would have been impossible.

The second step was taken at the meeting of the Astronomical and Astrophysical Society of America held at Ottawa in the summer of 1911, when a resolution was passed highly commending the work of the Observatory and urging the need of a larger aperture. This resolution was duly transmitted to the Minister of the Interior, the Hon. Frank Oliver, but coming just before the election and change of Government of 1911, was not of much avail.

A new start was made when the project was unanimously endorsed by the Royal Society of Canada at its May meeting in 1912. A strong memorial was drawn up, accompanied by letters of commendation from the Astronomer Royal for England and from the most prominent astronomers of Europe and America, and this was transmitted to the Premier who promised most careful consideration. Later in the year the Royal Astronomical Society of Canada also passed a resolution heartily endorsing the project.

A change of Ministers in the Interior Department somewhat delayed consideration of the matter, but when it was finally brought by the kindness and interest in astronomy of several members of Parliament to the attention of the present Minister,

the Hon. Dr. Roche, he gave it his sympathy and support and the cause was won.

May I be allowed to voice here the appreciation of the whole scientific world for the broad-minded action of Dr. Roche and of the Government in so splendidly helping on the cause of scientific research, and also the appreciation of the scientific men of Canada for making possible the placing of our country in the front rank in the development of its national observatory. I am glad also of this opportunity of expressing here my personal thanks to all those who so willingly gave their help and influence in advancing the cause.

The specifications which have already been printed* were drawn up after consultation with those astronomers of this continent who have had experience in the use of large reflecting telescopes and with opticians and makers of telescope mountings. They embody those features, which, in my belief, were the best of the many and sometimes conflicting views obtained, with some ideas of my own. I am glad to be able to bear tribute to the kindliness with which I was everywhere received and the willingness with which advice and help were given.

The telescope, which is to have a parabolic mirror of 72 inches clear aperture and 30 feet focal length with a central hole 10 inches in diameter, is to be mounted, similarly to the Melbourne and Ann Arbor reflectors, with the skeleton tube at one side and nearly midway between the bearings of the long polar axis, the balance being restored by the declination motion mechanism and by counterweights at the other side. The general form of the mounting is well shown in the figure. Plate XXII.

The instrument will be used primarily for spectrographic observations of stellar radial velocities, following some definite programme of work organized in co-operation with others interested in the same line. For this purpose, the telescope will be used in the Cassegrain form. In this arrangement the light reflected by the main mirror, and converging towards the focus, is received by a second convex hyperboloidal mirror of about 19

*This JOURNAL, Vol. VII., p. 217, May-June 1913.

inches aperture and 10 feet focus placed about 23 feet above the main mirror. The resultant focal length of the combination will be 108 feet and the star images will be formed about 3 feet below the face of the main mirror, the light passing through the hole in it. The spectrograph will be attached below the cell, which is a very convenient position as the change of position due to diurnal motion will be small. All high and moderate dispersion spectrograms will be made here but it is likely that for the fainter stars a low dispersion spectrograph will be attached at the prime focus where, owing to the shorter focal length, 30 feet, the images will be considerably smaller and more star light will get through the slit.

In addition to the spectrographic work, it is planned to have the telescope available for the direct photography of nebulæ, clusters, or other small areas of the sky. These will be made either at the prime focus of the 72-inch mirror or at the side of the tube by reflection from a Newtonian flat about 3½ feet below the focus. Following will be effected by a double-slide plate-holder with all the necessary following eyepieces, etc., carrying a plate 4 inches square. This size covers an area of about 40 minutes of arc square, all the field of good definition available with an aperture ratio of one to five. It will be possible also to make photographs in the Cassegrain focus, the 10-inch hole in the mirror giving a field of nearly half a degree.

The telescope will also be supplied with a full complement of oculars for visual observations at the Cassegrain and at the prime or Newtonian foci, although it is quite unlikely that any programme of visual work will be undertaken.

The principal consideration, not only in the preparation of the specifications but also in the design of the telescope, has been to enable the work described above to be done in the most efficient and convenient way possible with the simplest possible mechanical design. Both the writer, who has been responsible under Dr. King for the specifications and for some features of the design, and the Warner and Swasey Co., who have designed the workmanlike and well proportioned preliminary mounting shown in the

figure, have been in entire accord in the determination to make this telescope at least as efficient and convenient as any ever built and a great deal simpler in construction. To this end the specifications call for carrying the polar and declination axes entirely on ball or roller bearings, these serving both for relieving the friction and for aligning or collimating the axes, in place of using plain bearings for collimating and a complicated system of counterweighted rollers for relieving the friction. They call for the omission of all fine circles, of the slow motion arm in right ascension and for simplification in many other ways.

The Warner and Swasey Co. have further improved and simplified the mounting by omitting the slow motion arm in declination, the one motor serving for both quick and slow motion ; by directly attaching the clock to the driving worm, using spur gears only ; and especially by doing away with the numerous cumbrous "cages" or separate upper ends of the tube carrying the mirrors and attachments necessary for work at the prime focus, at the Newtonian focus and at the Cassegrain focus. This improvement, due to the genius of Mr. Swasey, worked out by their engineering staff, with some modifications suggested by the writer, provides, in the simplest possible way, by detaching one comparatively light piece and attaching another, for changing from one use to another of the instrument in a very few minutes and practically without change of balance. By the method previously used the separate "cages" with a 72-inch telescope would have weighed in the neighborhood of a ton, and would have required much longer time to change from one form to another, with some risk in handling and great labor in changing balancing weights, to say nothing of the much greater cost of construction.

Numerous other refinements and conveniences in use, with simplifications in mechanism, have been devised and will be incorporated in the new telescope, but space does not permit a detailed reference to them.

Both of the firms who have been entrusted with the construction of the instrument are taking the greatest interest and pride

in making this the best, as well as the largest telescope yet built.

The John A. Brashear Co. is a firm whose name is familiar to every reader of this JOURNAL and whose reputation for making high class mirrors and objectives is unsurpassed and indeed unequalled in the world. They bring to the task of making a six-foot mirror the skill and experience gained in the construction of two 37-inch mirrors and numerous smaller ones, as well as that acquired in the making of high class telescope objectives of large aperture. In order to satisfactorily test the figure of the large mirror the company are making a plane mirror of 55 inches in diameter and are preparing the additional equipment necessary for handling such large work.

For the Warner and Swasey Co. it is only necessary to say that their reputation in the way of telescope mountings is unequalled anywhere. They have made the mountings of the two largest refractors in the world which have, from the first, given perfect satisfaction. They bring to this new problem all the experience gained in their earlier work and the resources of their high class engineering staff. For after all the mounting of a great telescope is an engineering problem and Warner and Swasey's great success in the mounting of telescopes has been due to their getting away from the instrument maker's ideas and attacking the problem from an engineering standpoint.

I am firmly convinced that in this instrument, when it is completed, Canada will have a telescope, not only very considerably larger than any in use, but also one of the very highest quality and capable of doing, with the minimum expenditure of time and labor and in the best manner, the work for which it has been designed.

In order, however, that such a telescope may be used to its full advantage and that it may be able to turn out the highest class of work it is of the utmost importance that it be located where the astronomical conditions are most favorable. An investigation for the purpose of determining the relative suitability of various places in Canada is now being carried on.

In order to correct what seems to be quite a prevalent misapprehension in regard to the conditions suitable for a large reflecting telescope, I wish to state that the place having the largest quantity of clear night sky is not necessarily the best place and that this factor is by no means the most important to be considered.

The four principal conditions that will govern the choice of a location are, in order of importance: the "seeing," referring to the steadiness and sharp definition of the star image; the daily temperature gradient, especially the change of temperature during the observing hours; the transparency of the sky or freedom from haze or smoke; and the quantity of clear night sky. The first two conditions are by far the most important, for while differences of transparency may make a difference in efficiency of say 30 per cent. and the quantity of clear night sky may vary over different regions, otherwise suitable, in Canada by 20 per cent, differences of seeing and of temperature gradient may make a difference in the quantity of work turned out of two or three to one and in quality between good work and that quite inferior in quality or untrustworthy.

Poor "seeing" becomes increasingly troublesome as the aperture increases, for not only is the cylinder of incident parallel light larger in diameter and encounters greater disturbances in the air through which it passes, but the displacements and lack of definition of the image are magnified in direct proportion to the increase of focal length. Conditions that would cause little trouble in a moderate aperture might in a 72 inch telescope practically prevent its effective use.

A large drop of temperature during the night is only second to bad seeing in causing troubles with a large reflector. For a change of temperature distorts the mirror surface and hence spoils the definition, having a similar effect to bad seeing so far as the use of the instrument is concerned.

It will hence be realized how important it is to place the new telescope where good seeing is combined with a low diurnal range of temperature. If with these two factors are combined

good transparency and a large amount of clear sky so much the better, but if not the first two conditions should be given two or three times the weight of the others in making a selection.

It is very much to be hoped that the new reflector will be placed at the location in the Dominion where it can be used to the best advantage and where the scope, quantity and quality of the work will not be limited by unfavorable atmospheric conditions.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
December, 1913.

MEETINGS OF THE SOCIETY

At Toronto.

October 7, 1913. — The meeting was held in the Society's Rooms, 198 College St., at 8 p.m.

The Secretary referred to communications which he had received from Regina and which reported the progress being made by the officers and members of that Centre in obtaining a telescope to be used by the members and the public ; and explaining also how the Society was being promoted in other ways.

Colonel William R. Winter, Waterville, Paget East, Bermuda.

Mr. Herbert E. Brown, 289 Robert St., Toronto, were elected members of the Society.

Mr. J. R. Collins gave an account of observations that have been made recently on Jupiter, taking note of the changes in the configuration of the equatorial belt.

Mr. D. J. Howell, a charter member, showed some very good examples of slides made of color photographs which were excellent and very much appreciated by those present. A resolution was passed congratulating Mr. Lachlin Gilchrist upon having obtained the degree of Ph.D. at Chicago University.

Professor C. A. Chant gave the lecture of the evening on "Interesting Stellar Objects of the Autumn." Dr. Chant first gave an account of the interest that had been aroused in meteors, as shown by the collection of letters that he had received in connection with the meteor shower of February 9th.

He then took up astronomical objects and elaborated the

information presented in the HANDBOOK. In this connection Dr. Chant discussed phenomena associated with the sun, moon, Saturn, Jupiter and Mars. Then he took up the Constellations and the method of presentation in the HANDBOOK and considered in detail the stars visible in September.

The form and method of use of a plainisphere with samples on the market and some made by students under Dr. Chant were also described.

October 21st. — The paper of the evening was by the President of the Society, Professor L. B. Stewart, on "The Great Star Map."

Professor Stewart gave a brief historical account of the determinations of the position at sea, from observations on the stars and of the work of Flamsteed and the establishment of Greenwich Observatory. Then he gave an account of the making of the great star list by Bradley. The lecturer then took up the methods of measuring the Right Ascension and Declination of the stars, and described carefully the methods of photography in making true measurements and pointed out the difficulties associated with photography when using a refracting telescope.

Professor Stewart then described in detail the project instituted by the Convention of Astronomers in Paris, 1887, for the preparation of the Great Star Map by the co-operation of 14 of the prominent observatories of the world and outlined the results that have been obtained through the project.

L. G.

[Other minutes of the Meetings of the Society are held over until next issue].

NOTES FROM THE DOMINION OBSERVATORY

A NEW PRISM FOR SPECTROGRAPH I.

For some time doubts have been felt by the writer as to the suitability of the dense flint *O* 102 glass used almost universally for the prisms of stellar spectrographs. It is quite markedly yellow and it has been experimentally shown to be strongly absorbing from about λ4000 down. In many early type spectra the *K* line is by far the best measurable and most dependable line in the whole spectrum. In many other early type stars only the hydrogen lines are present and if the number measurable could be increased the accuracy would be improved. With the *O* 102 prism we have been using, the *K* line can only be obtained by nearly doubling the exposure required between $H\beta$ and $H\gamma$, and this results in blocking up any narrow lines in the latter region; while $H\epsilon$ is the most refrangible hydrogen line measurable.

Some months ago some experiments on the use of a plane grating as dispersion piece were tried. Unfortunately only about 30 per cent of the incident light was diffracted into the first order spectrum used and consequently, although the spectra were much stronger to the violet, there was not much improvement at *K* and to the blue they were weaker. There was considerable improvement in uniform intensity of the spectra but on the whole it was not deemed advisable to replace the prism by the grating.

Not much experimental data as to the absorption of different glasses could be found. Some experiments by Wilsing on the absorption of ordinary silicate crown *O* 203, ordinary light flint

O 340 and dense silicate flint *O* 102 showed that the light flint transmitted over twice as much *K* light as the *O* 102. It was judged, from the general rule that the absorption is in some sort of inverse ratio to the relative dispersions, that one of the baryta light flints *O* 722 would be the most suitable.

A prism of *O* 722 glass of 2 inches aperture was ordered from the John A. Brashear Co. In order to use it in the Ottawa single prism spectragh which gives a deviation of 60° it was necessary to make the refracting angle nearly 69° instead of 63° 40′ for the *O* 102. The central wave length was moved from λ4325 to λ4200 for obvious reasons when more of the violet was to be obtained, and the angle of the prism became 68° 57′.

This prism, a beautiful piece of glass, very clear and colorless, has recently been received and mounted in the spectrograph. It gives star spectra very uniform in intensity from H_β to considerably beyond *K* and shows a remarkable saving in exposure time for the region around *K*. The dispersion is almost exactly three-fifths that of the *O* 102 prism or about 55Å to the millimetre at H_γ. This could if desired be made equal to the *O* 102 by increasing the focal length of the camera lens.

So far as the data at present extend, the relative exposures required *when the dispersions are made the same* are expressed in the following table : —

Wave Length		Relative Exposures	
		Baryta Light Flint	Dense Silicate Flint
		O 722	*O* 102
$H\beta$	4861	0·60	1·00
$H\gamma$	4341	0·65	1·00
Hg	4102	0·50	1·00
$H\varepsilon$	3970	0·36	1·00
K	3933	0·26	1·00
$H\zeta$	3889	0·12	1·00

Furthermore with an exposure on early type stars of about half that given with the dense flint prism, six hydrogen lines

beyond H_ϵ are of sufficient intensity to be measured, while $H\zeta$ is not sufficiently strong with the dense flint.

It seems to me therefore that the use of a similar material to this should be very seriously considered in preference to *O* 102 when any new spectrographs are projected. Although there would not be so much advantage in its use in solar type stars, it is unquestionable that for stars of types *B*, *A*, and *F* the use of the lighter flint would not only give many more measurable lines in spectra where the lines are generally few but would also effect a great saving in exposure time.

December 15, 1913. J. S. P.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

October, 1913

Temperature.— Over the greater part of British Columbia temperatures for the month were from 1° to 3° below normal. White frost was recorded on 3 or 4 days on Vancouver Island and the Lower Mainland, and heavier frosts more frequently further in the interior. In the Western Provinces, the month began with maximum temperatures of from 65° to 80°, but after the 3rd the weather became much cooler, and heavy frosts were recorded during the latter part of the month. On the last day of the month several stations recorded temperatures of zero or a little below. Mean temperatures for the month were from 2° to 9° below normal. In Ontario the difference from normal temperature was negative in the Lake Superior Districts, but positive over the remainder of the province, where it ranged from 1° to 5°, the greatest differences occurring along the Ottawa River. In Quebec the mean temperature exceeded the normal by about 5° along the St. Lawrence and in the Lake St. John District, and by about 2° in the northwestern districts. In the Maritime Provinces, the month was remarkably warm, the excess over normal ranging from 6° to 11°.

Precipitation. — Except in the Kootenays and locally in the southwestern part of the province, the precipitation was considerably greater than normal. The mean amount on Vancouver

Island was 5 inches, on the Lower Fraser River 6½ inches, along the Upper Fraser 2½ inches, in the Okanagan Valley and the West Kootenay 1¾ inches, in the East Kootenay less than half an inch, along the Thompson River 1½ inches, and along the North Columbia River 3¾ inches. In Alberta the amount of precipitation ranged from little more than a trace, to 1¼ inches. The average amount for the whole province was about half an inch. In Saskatchewan the precipitation averaged one inch along the Qu'Appelle River and somewhat more than half an inch in the basin of the South Saskatchewan River; while in the basin of the North Saskatchewan River less than a quarter of an inch was recorded. In Manitoba the precipitation was very evenly distributed, and averaged nine-tenths of an inch for the whole province. The precipitation in Ontario was in excess of the normal, except in the West Central Counties, the Lake Ontario Region and the East Central Counties, where the average was less than 3 inches. In the Lake Huron Counties the fall was exceptionally heavy, averaging nearly 5 inches. In Quebec, along the Middle and Lower St. Lawrence, the precipitation averaged about 5 inches, or about 2 inches more than normal. In the country north of the river the amount averaged about 3¼ inches. In New Brunswick the amount averaged 5½ inches, in Nova Scotia and Prince Edward Island 8 inches. The excess over normal was about 3 inches in New Brunswick, and between 4 and 5 inches in Nova Scotia.

November, 1913.

Temperature. — On Southern Vancouver Island, on the Southwestern Mainland, and on the Upper Fraser, temperatures for the month were from 1° to 2° below average, while in the Thompson Valley and in the southeastern part of the province there was a positive departure. In the Western Provinces the month was an unusually mild one, mean temperatures ranging from 5° to 9° above normal. In Ontario, likewise, mild conditions prevailed, the positive departure ranging from 4° to 8°

Temperatures for October and November, 1913

Station	October		November	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson			46	30
British Columbia				
Atlin	48	17	41	-8
Agassiz	66	30	61	25
Barkerville	56	12	49	4
Kamloops	72	22	63	18
New Westminster	64	29	53	26
Prince Rupert	58	36	64	30
Vancouver	60	33	52	30
Victoria	62	35	56	31
Western Provinces				
Battleford	76	0	55	0
Broadview				
Calgary	85	11	60	3
Carman				
Edmonton	78	11	59	3
Medicine Hat	81	19	61	9
Minnedosa	78	0	54	-6
Moose Jaw	75	0	59	7
Oakbank	71	0	54	0
Portage la Prairie	79	6	60	9
Prince Albert	69	3	55	2
Qu'Appelle	72	4	53	5
Regina	72	-2	40	15
Swift Current	74	3	62	1
Winnipeg	73	5	59	7
Ontario				
Agincourt	83	24	64	25
Aurora	79	26	63	23
Bancroft	82	16	63	12
Barrie				
Beatrice	76	15	62	20
Birnam	77	28	67	23
Bloomfield	75	24	61	22
Brantford	84	26	67	24
Bruce Mines	73	14	58	16
Chatham	87	29	71	21
Clinton	79	21	65	23
Cottam	82	21	67	11
Gravenhurst	78	21	62	20
Guelph	81	23	65	23
Haliburton	80	10	62	13
Hamilton				
Huntsville	80	15	61	20
Kenora	61	6	58	-4
Kimmount	77	17	63	15
Kingston	74	22	60	22
Lakefield	76	22	68	20
London	83	26	67	19
Lucknow	79	19	63	20
Madoc	79	21	62	19
Midland			62	30
North Gower	80	12		
Otonabee				
Ottawa	76	23	64	18
Owen Sound	77	18		
Paris	82	27	66	25
Parry Sound	78	17	60	20
Peterboro'	85	21	64	20
Port Arthur	63	8	54	1
Port Burwell	74	26	58	24
Port Dover	80	26	61	20
Port Stanley	72	26	57	20
Ronville	79	18	60	18
Sarnia				
Southampton	80	25	65	26
Stonecliffe	80	20	57	13
Stony Creek	78	29	67	27
Stratford	80	23	60	22
Toronto	81	27	64	27
Uxbridge	80	22	63	23
Wallaceburg	83	27	66	17
Welland	77	28	65	23
White River	71	2	52	1
Quebec				
Brome	77	26	64	13
Father Point	70	26	68	2
Montreal	74	25	62	17
Quebec	73	24	61	13
Sherbrooke	77	24		
Maritime Provinces				
Charlottetown	68	33	60	22
Chatham	75	30	64	6
Dalhousie	70	29	58	5
Fredericton	76	26	62	4
Halifax	76	30	67	21
Moncton	73	23	62	8
St. John	69	30	62	12
St. Stephen	74	26	65	6
Sussex	71	26	62	6
Sydney	70	32	61	14
Yarmouth	74	39	65	15

except locally in the Lake Erie Region, where it was somewhat less. Throughout Quebec temperatures were from 4° to 5° above normal, while in the Maritime Provinces the mean was in some districts above normal and in some districts below normal, the departure being nowhere large.

Precipitation.—Precipitation for the month in Southern Vancouver Island and the Lower Fraser River ranged from 5 to 16 inches, in the Upper Fraser about 5 inches and in the dry belt about an inch. In Alberta and Saskatchewan only from 5 to 30 per cent. of the normal precipitation occurred, while in Manitoba the fall was greater, small positive departures being recorded locally. In most districts of Ontario there was an excess, reaching as high as 80 per cent. locally in the Western Lake Ontario Region. In many parts of the Upper St. Lawrence and Lower Ottawa Valleys, however, there was generally a deficiency. Eastward from Ontario precipitation was everywhere below normal, being only from one-third to two-thirds of the average in Quebec, and from one-quarter to one-half in the Maritime Provinces. Snow fell nearly everywhere in the Dominion during the month, heavily in Western Ontario, Western Manitoba and parts of British Columbia, while in other sections the fall was light. At the end of the month the snow had in most sections of the country either disappeared or occurred only in patches.

MAGNETIC OBSERVATIONS

During the month of October, with the exception of the week beginning on the 4th, the magnetic curves obtained at Agincourt were normal. For the week of disturbance the *D* curves were for the most part normal during the day time and disturbed at night, the times of beginnings of disturbance showing a marked tendency to periodicity. The times were $4^d\ 22^h\ 3^m$; $5^d\ 21^h\ 11^m$; $6^d\ 20^h\ 12^m$; 7^d uncertain; $8^d\ 17^h\ 40^m$; $9^d\ 16^h\ 40^m$. The maximum of disturbance occurred on the night of the 5th. A rapid diminition of 21'·5 of W. Declination in 20 minutes of time was followed by a series of long waves extending to each side of normal and gradually disappearing during the early morning of the 6th. The *H* curves were more or less disturbed during the whole week, the maximum occurring co-incident with that of Declination but the disturbance in *H* showed no tendency to periodicity.

A small group of sun-spots was observed on the 5th, 6th and 7th, central on the morning of the 7th and then diminishing in area and disappearing.

During the month of November both *H* and *D* curves were unusually quiet even for a period of minimum sun-spots. Only on 6 days were even small disturbances recorded.

Declination

Month	Mean of Month	Max.	Date	Min.	Date	Monthly Range	Amplitudes—Mean Daily: From hourly readings	Amplitudes—Mean Daily: From Means of Extremes
1913	° ′	° ′		° ′		° ′	′	′
Oct.	6 19·4	6 36·2	8	5 51·2	4	0 45·0	7·3	14·4
Nov.	6 19·9	6 29·7	7	6 05·1	2	0 24·6	6·4	9·7

Horizontal Force—C.G.S. Units

1913								
Oct.	·16109	·16136	4	·15973	6	·00163	·00026	·00048
Nov.	·16111	·16140	12	·16069	2	·00071	·00023	·00036

Inclination

Month	Mean Earth Inductor
1913	° ′
October	74 41·6
November	74 41·2

Earthquake Records by the Milne Seismograph

TORONTO

R. F. Stupart, Director.

P.T. = Preliminary Tremors. L.W. = Large Waves. A.C. = Air Currents.

Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1913	P. T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm	h m	
1289	Oct. 2	4 31·9	4 38·7	4 46·4	6 43·4	8·0	2 11·5	Panama.
1290	" 4	22 9·4 17·5	22 20·2 22 26·7	22 28·8	23 32·9	1·4	1 23·5	Eq. reported from Panama.
1291	" 8	6 24·9			6 46·0	0·1		
1292	" 9	18 43·9?	18 51·8		19 39·2	0·3	0 45·3	
1293	" 11	2 5·4 2 26·6	2 41·5		4 5·5	0·1	2 0·1	P Ts. doubtful
1294	" 11	4 37·9?	4 54·9 5 6·0	5 27·2	7 5·5	0·8	2 27·6	
1295	" 11	9 28·0	9 48·1	9 55·7	11 9·0	0·3	1 41·0	
1296	" 14	6 51·8			7 1·0	0·05	0 9·2	
1297	" 14	8 29·0	8 39·0	8 39·5 9 33·7	11 17·0	0·3 0·7	2 48·0	
1298	" 14	22 14·2		A.C.?		0·05		
1299	" 23	15 15·3	15 18·4	15 25·6	16 9·0	0·8	0 43·7	
1300	" 26		13 49·8	13 50·2	14 8·9	0·2	0 19·1	
1301	" 26	23 3·2 10·1	23 17·4	23 20·9	0 2·7 0 29·5	0·3	1 26·3	
1302	" 29	5 54·1	5 59·5 6 2·8	6 3·5	6 15·6	0·2	0 21·5	
1303	Nov. 4	10 19·3	10 31·8	10 36·7	11 7·2		0 47·9	
1304	" 10	21 37·9 21 42·9	22 9·8 22 11·1	22 32·4	0 1·0	0·9	2 23·1?	Eq. reported from Peru.
1305	" 15		6 48·5		7 10·5	0·05	0 22·0	
1306	" 19	3 55·0	4 0·5		4 15·3?	0·1	0 19·7	
1307	" 23	21 44·4			22 24·0	0·05	0 39·6	

Period 17·7 seconds. 1 mm. = 0″·59.

VICTORIA, B. C.

E. B. REED, SUPERINTENDENT.

No.	Date 1913	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1291	Oct. 2	4 34·9	4 52·7	5 2·3	6 24·5	1·0	1 49·6	Panama.
1292	" 4	22 26·6?	22 34·9		23 2·0	0·2	0 35·4	Real P.Ts. may not have been recorded.
1293	" 8	6 9·0?			6 30·9	0·05	0 21·9	
1294	" 9	18 55·6	19 9·7		19 34·6	0·2	0 39·0	
1295	" 9		23 19·3 23 29·2		0 2·8	0·1	0 43·5	
1296	" 11	1 57·0	2 19·4 2 26·4		4 1·7	0·8	2 4·7	
1297	" 11	4 14·3	4 39·0	5 3·7	6 59·3	1·8	2 45·0	
1298	" 11	9 28·0	9 48·1	9 55·7	11 9·0	0·3	1 41·0	
1299	" 14	6 56·2			6 58·2	0·05	0 2·0	
1300	" 14	8 21·8	8 31·2	8 35·2	11 18·5	0·2	2 56·7	
1301	" 14	22 11·3 22 13·9			22 23·8	0·05	0 12·5	
1302	" 23	15 31·1?	15 37·7	15 39·3	16 8·6	0·2	0 37·5	P.Ts. doubtful.
1303	" 26	13 45·8	13 49·4	13 48·3	13 53·3	0·1	0 7·5	
1304	" 26	23 0·9	23 2·9	23 7·7	23 23·5	0·3	0 22·8	
1305	" 29	5 52·4			5 53·4	0·05	0 1·0	
1306	Nov. 4	10 21·8	10 38·8 10 43·9	10 44·9	11 15·0	0·2	0 53·2	
1307	" 10	21 35·5	21 54·9 21 56·7	22 12·3	0 9·3	1·7	2 33·8	
1308	" 15	6 13·3	6 38·0		6 45·2	0·05	0 31·9	
1309	" 17	22 8·7			22 14·4	0·1	0 5·7	
1310	" 17	22 34·9			22 37·4	0·05	0 2·5	
1311	" 19	3 51·0			4 6·0	0·1	0 15·0	
1312	" 23		21 36·5 21 48·2		22 4·3	0·05		P.Ts. lost attending to instrument.

Period 18 seconds. 1 mm. = 0″·54

J. V.

ASTRONOMICAL NOTES

THE ORIGIN OF CLIMATIC CHANGES. — The discussion of meteorological observations shows clearly that climates undergo variations of short duration, but such records as the presence of old lake beaches and the existence of well-marked glacial moraines, and other geological evidence distinctly point to climate changes covering long intervals of time. The evidence is not sufficient to characterise the variations as periodic, but the ice ages are sufficient to point to times when the conditions reached were extreme.

What may reasonably be assumed to be the chief established facts about extensive changes may be summed up briefly as follows: — Climatic changes were several, and probably many. Similar simultaneous changes occurred over the whole earth, or, in other words, it was warmer or colder over the whole earth simultaneously. These times of warmth or coldness were unequal in intensity and duration, and of irregular occurrence, and, lastly, they have taken place from very early, if not from the earliest geological age down to the present. Numerous theories, both probable and improbable, have been suggested from time to time to account for the origin of such world-wide changes, and while each has its advocates, perhaps only three may be said to claim attention to-day. These may be briefly stated as the Eccentricity Theory (Croll), depending on the eccentricity of the earth's orbit; the Carbon Dioxide Theory (Tyndall), based on the selective absorption and variation in amount of carbon dioxide; and thirdly, the Solar Variation Theory, on the assumption of solar changes of long duration.

A new theory, which may be called "The Volcanic Dust and Solar Variation Theory," has recently been put forward by Professor W. J. Humphreys, of U. S. Weather Bureau, under the guarded heading, "Volcanic dust and other factors in the production of climatic changes, and their possible relation to ice ages."—*Nature*, No. 2304.

A Leader in the Progress of Astronomy.—Although astronomers had been classifying stars according to their spectral types, it remained for Kapteyn, through his study of stellar velocities, to find that these two methods of classification, according to spectral types and according to velocity, agreed. To know the velocities of the different types of stars was to be able to arrange them in their proper place in the great plan of evolution. It appears that as a star progressed in age its velocity was accelerated. Following this to its logical conclusion, he inferred that the irregular nebulæ, possessing small linear velocity, must be the birth place of the stars, but the planetary nebulæ, which show greater velocity than do the stars, must form the final link in the chain of stellar evolution.

Other astronomers are working toward the solution of the same problem, but to Kapteyn belongs the glory of the discoverer. He was the first to enter this field and it is to him that the world is turning for the answers to its questions. Too much honor cannot be given to those men, who, after the example of Tycho Brahé do the monotonous observational work, without which none of the more spectacular achievements would be possible. Their reward may not consist in world-wide fame, it lies rather in the consciousness that they are helping their beloved science and the cause of learning as a whole. Those who build upon their work realize its importance. It is through their efforts that these others, these men who are working toward an adequate conception of this vast universe, have been enabled to make the progress that has been registered. And it is by leaders like Kapteyn, an inspiration both to the army of observers and to other leaders, that the standards of astronomy are

advanced. Through the combined efforts of these two types of genuis we must ever look for a disclosure of new laws. Even now there are indications that we are on the verge of the discovery of new truth as far-reaching perhaps as the law of gravitation. — DOROTHY BACH, in *Publication Astronomical Society*, Pomona College, 1913, No. 4, Claremont, Cal., U.S.A.

RADIAL MOTION IN SUN-SPOTS. — The differing displacements shown by the Fraunhofer lines at the peripheral edges of the penumbræ of eccentrically located sun-spots seem to find their simplest explanation in movements of the solar vapors tangential to the solar surface with velocities varying with the elevation.

Assuming as a standard the series of displacements shown by the *Fe* lines, the relative levels of the lines of 26 other elements of the reversing layer and chromosphere have been determined and plotted in a chart of distribution.

The resulting distribution shows that the H, and K, lines of calcium are the lines of highest level, followed by the H_α line of hydrogen, and that, in the main the heavy and rare elements occur in detectible amounts only in the lower portions of the solar atmosphere.

A comparison of the radial displacements with the weakening and strengthening of spot lines shows that strengthening increases with depth, and that weakening is associated with high elevations.

When the strength of the magnetic field in sun-spots is calculated from the separations in spot spectra and the laboratory separations of the same lines in known magnetic fields, widely different values are obtained, but when the lines are assigned to the relative levels indicated by their radial displacements the field strength decreases consistently with elevation.

The displacements of the Fraunhofer lines in the penumbræ of sun-spots give a means of sounding the solar atmosphere and of assigning relative levels to the sources of the lines. Aside

from the inherent probability of the interpretation, it is confirmed by eclipse results and is in harmony with a wide range of solar observations, and opens the way to further solar research. — CHARLES E. ST. JOHN, in *Astrophysical Journal*, No. 4.

NEBULÆ WITH LARGE RADIAL VELOCITY. — Professor Campbell and E. S. Haynes, of the Lick Observatory, state in *Publications Astronomical Society of the Pacific*, No. 131, that the velocities of approach or recession recently determined here for fifteen nebulæ are in accord with Keeler's results for thirteen other (planetary) nebulæ, *viz.* : the average velocity is high.

The tenth-magnitude planetary nebula, (R.A. $19^h\ 11^m{\cdot}0$, Dec. $-19°\ 14'$), has an abnormally high velocity. The mean of the observed velocities obtained from three photographs is approximately 150 km. per second, recession, with reference to the Sun ; or correcting for the effect of the solar motion, 165km. per second with reference to the stellar system.

The results for the other fourteen nebulæ vary from about 60 km. approach per second to about 60 km. recession, with reference to the stellar system.

In the same publication J. H. Moore describes another one. Two spectrograms of the planetary nebula (R.A. $15^h\ 6^m{\cdot}3$; Dec. $-37°\ 43'$), were obtained with the one-prism spectrograph at the D. O. Mills Observatory, Santiago, Chile, in March, 1913. The mean of the measures of these two plates by Miss Hobe, Mrs. Moore and Mr. Moore give for the radial velocity of the nebula with reference to the Sun -236 km. per second. Its velocity in the line of sight referred to the stellar system is therefore -133 km. per second.

And W. S. Adams and A. Kohlschütter, describes a star with remarkable Radial Velocity. In the course of our observations of the radial velocities of the fainter stars with measured parallaxes, we have found the star Lalande 1966 (α 1900 $1^h\ 3^m{\cdot}3$) to have an extraordinarily high velocity.

The spectral type of the star is F3. The parallax of the star as found by the Yale observers is $+0''{\cdot}08$. If we assume

this value and the proper motion given by Kapteyn, we find the motion in space to be 320 km. per second, directed towards the apex.

THE DYNAMICS OF A GLOBULAR STELLAR SYSTEM.—The force which at any moment acts on a star may be regarded as made up of two parts, *viz.*, the central attraction of the whole stellar system, and the force due to the chance arrangements of the stars in the immediate neighborhood. The appropriate dynamical theory depends on the relative importance of these two components. By an argument from the existence of moving clusters of stars which, though widely separated in space, have preserved closely equal and parallel motions for a vast period of time, I have been led to the conclusion that the effect of the stars in the immediate neighborhood is of negligible amount. This appears to be confirmed by direct numerical estimates of its probable value. The discussions in this paper relate therefore to stars moving under the general attraction of the system; there will be no chance deflections or encounters, and consequently the theory differs fundamentally from the dynamical theory of gases, to which some resemblance might at first sight have been expected.

The actual discontinuous field of gravitational force, due to a number of point-centres (stars), is thus replaced by a continuous field due to a smoothed distribution of density. It is necessary to form a rough idea of this density. We know of about 20 stars contained in a sphere whose limit corresponds to a parallax of 0″·2. Doubtless there are some others yet to be found; and there may be almost any number of dark stars. Although many of the 20 stars are much fainter than the sun, there masses are probably not greatly less. We shall probably be considerably underestimating the density if we take the matter in this sphere as ten times the sun's mass. If the universe were a globular system of this density, each star would describe an elliptic orbit about the centre of the system in 300,000,000 years — a period less than current estimates of the age of the earth. The period

is independent of the size of the orbit or of the system. It seems probable then that a mature star will have made at least one, and probably many journeys round its orbit since it came into existence. We are therefore justified in thinking of the stellar orbits as paths which have been actually traversed and not as mere theoretical curves.

If we wrote down at random an arbitrary distribution of motions in a stellar system, we should generally find on tracing backwards the past positions of the stars, that the distribution of stellar density became irregular and fantastic, such as we must reject as very unlikely to have occurred in the past history of the universe. By this kind of criterion certain velocity-distributions can be rejected, and others selected as possible — that is not leading to any inconsistency or improbability. Amongst the selected possible distributions, there is one important class, namely, those which correspond to a steady state of the stellar system. These clearly can lead to no inconsistency ; for the past arrangement is the same as the present. I do not know that any evidence can be adduced to show that the stellar system is in a stationary or quasi-stationary state ; but it seems to be the proper starting point in the study of a new kind of dynamical system ; and it is entirely in accordance with the precedents of hydrodynamics and molecular dynamics to consider the possible steady states of motion. — A. S. Eddington, in *Monthly Notices* R. A. S., November 1913.

J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

QUERY

Why could not a coronal line be used to obtain a photograph of the corona in the same way as the photosphere is photographed by the aid of the calcium or other line? Are they too faint or in some other way interfered with? T. H. W., (Hamilton).

ANSWER

By the Director of the Yerkes Observatory:

In reply to your question, the only reason why the corona cannot be photographed by the coronium line is that it is too faint relatively to the brightness of the earth's atmosphere. I see no reason why it should not be possible at a sufficient elevation on the earth's surface; but that elevation might be five miles or more.

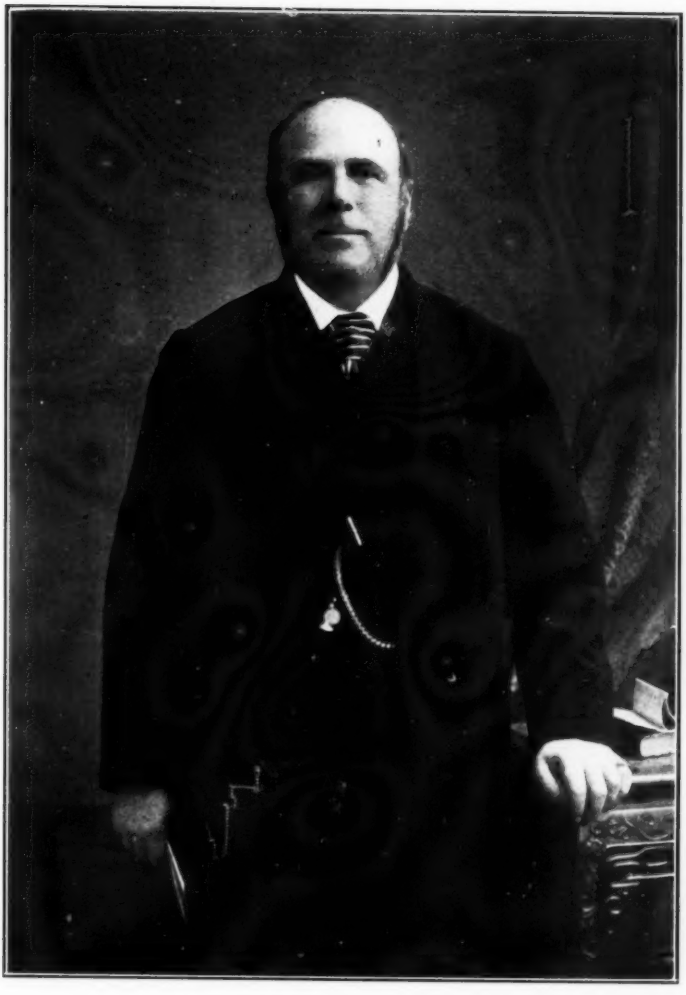
EDWIN B. FROST.

DEATH OF SIR ROBERT BALL.

A well-known figure in the astronomical world passed away when Sir Robert Ball died on November 25, 1913.

Robert Stawell Ball was born in Dublin, July 1, 1840, his father being Robert Ball, LL.D., a well-known naturalist. He was educated at Trinity College, Dublin, which institution afterwards conferred the LL.D., degree upon him. Cambridge University gave him the degree of Hon. M.A. in 1892. He was knighted in 1886; he was also an F.R.S., Ex-president of the

PLATE XXIII.



Robert S Ball

Born July 1, 1840: died November 25, 1913.

R.A.S., Ex-president of the Royal Zoological Society of Ireland, and an Honorary Fellow of our own Society.

From 1874 to 1892 Ball was Royal Astronomer for Ireland. In the latter year he was made Lowndean Professor of Astronomy and Geometry at Cambridge, and Director of the Cambridge Observatory and these positions he held until his death. He was also scientific adviser to the Commissioners of Irish Lights from 1884.

Many memoirs on mathematical, astronomical and physical subjects were published by Ball, and although he did considerable original work he was best known as a popular lecturer and a writer of popular scientific books. "The Story of the Heavens", first published in 1885, and "Starland", 1889, have been very widely read and admired. Besides these may be mentioned: "Experimental Mechanics" (1871), "Time and Tide" (1889), "Cause of an Ice Age" (1891), "Story of the Sun" (1893), "Great Astronomers" (1895), "Treatise on the Theory of Screws" (1900), The Earth's Beginning" (1901), "In Starry Realms", "In the High Heavens", "Popular Guide to the Heavens" (1905), Treatise on Spherical Astronomy" (1908).

A METEOR SHOWER IN THE ARCTIC REGIONS

Mr. C. E. Bastin, B.A., the Secretary of the Winnipeg Centre, sends me the following interesting letter and enclosure:

I enclose an extract from "Hunting with the Eskimo" by Harry Whitney. As you will see, this contains a vivid account of an unusually brilliant meteoric shower which was witnessed by Mr. Whitney at Cape Leiter, at the north-east of Smith Sound, north of Baffin Bay. Mr. Whitney went north in 1908 on the *Roosevelt*, which was carrying supplies for the Peary expedition. When the *Roosevelt* returned he remained and spent the winter with the Eskimo.

The shower occurred in November, 1908, but the date is not given, as after the sun finally disappeared Mr. Whitney soon lost

count of the days, and on this particular expedition he had no watch with him.

It occurred to me that this account might be of interest to the readers of the JOURNAL, as I have not noticed an account of any such shower of November meteors in 1908.

"A long hard pull of many hours, with heavy drifts through which we had to help the dogs haul the komatiks, brought us to Cape Leiter. Here under the shadow of a towering bluff a halt was called. I threw up some blocks of snow for a windbreak, and in their lee started my oil stoves and put over tea and several pieces of hare to thaw out for all hands while the Eskimos built a snow igloo for our camp.

While thus busied we were treated to the most brilliant meteoric display I have ever witnessed. The whole heavens seemed filled with shooting "stars" crossing each other in every direction, many of them leaving long streaks of light behind. It was as though a million rockets of great size and power had been set off at the same moment, with other millions following in quick succession.

But inactivity in the intense cold had chilled me through and through, and when supper was eaten I was ready enough to relinquish the beauty of the night and shooting stars for the igloo and my sleeping bag, in a vain endeavor to get warm."

A REPORT FROM THE LUNAR SECTION

Mr. H. B. Collier, of Indian Road, Toronto, has an excellent three-inch telescope which he often uses, and in the course of his observations has had some amusing experiences. At the request of the present writer he gives the two following true incidents:

Bruce was just five years old. Naturally he took considerable interest in the moon, for he saw and heard his father continually peering at it and describing its peculiarities to visitors. A new moon appeared on the scene and as the little fellow caught sight of it through the window he called in frightened tone,

"Daddy, come quick, the moon's all broke".

I recently had a group of young men at my home and was

engaged on the front lawn with the telescope showing them the wonders of the moon, when one of those six-foot-six policemen, the pride of Toronto, came along on his bicycle. His curiosity evidently prompted him to alight and investigate. It was not long before I had him using his eyes at the instrument. Speechless he drew back and for a moment gazed with naked eye on the moon to assure himself apparently that he was not being deceived. Again he looked through the telescope and finally announced a discovery — for him —

"It's round. I always thought it was flat".

His education on pie had evidently not been neglected.

THE KINDNESS OF OUR FRIENDS

For the half-tone block used in printing the group-portrait of the delegates to the Solar Conference at Bonn, we are indebted to Editor Wilson of *Popular Astronomy*; while for that of Newcomb's portrait our thanks are due to Professor Frost. It was originally made for *The Astrophysical Journal*.

SIMON NEWCOMB: A CORRECTION

At the time of Professor Newcomb's death there appeared in this JOURNAL a sketch of his life, and the Editor added a note (Vol. III, p. 312, 1909), in which was given an account of a friendly meeting with the distinguished astronomer at the Lick Observatory in the summer of 1907. In a general conversation I understood Professor Newcomb to say that he had never seen the Grand Canyon of the Colorado. Afterwards Mrs. Newcomb wrote to me to say that there must have been some misunderstanding, as they had visited this great natural wonder. This is perhaps the most suitable time for me to make this correction.

C. A. C.

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